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U. S. DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

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MONTHLY WEATHER REVIEW

VOLUME 47, No. 7

JULY, 1919

WASHINGTON
GOVERNMENT PRINTING OFFICE
1919

INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological and seismological contributions and bibliography; (2) an interpretative summary and charts of the weatherof the month in the United States and on the adjacent oceans; and (3) climatological and seismological tables dealing with the weather and earthquakes of the month.

The contributions are principlaly as follows: (*a*) results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; and (*b*) abstracts of reviews of important meteorological papers and books. In each issue of the REVIEW such contributions and abstracts are grouped by subjects, roughly, in the following order: General works, observations and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture, weather, applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of such contributions is not to be construed as official approval of the views expressed.

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. Persons or institutions receiving We ather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U.pS. Weather Bureau, Washington, D. C.," in order that the monthly list of current works on meteorology and seismology may be as complete as ossible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW.

The section on the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans, and ome notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meterological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

Supplements containing kite observations and others containing monographs or closely related collections are published from time to time.

SOME WEATHER BUREAU PUBLICATIONS.

Serial numbers of Weather Bureau publications	Free.
The Weather Bureau. (Descriptive pamphlet)	Free.
Report of the Chief of the Weather Bureau, 1917–18 (4° edition)	Free.
National Weather and Crop Bulletin, with charts, monthly from October to March, weekly during remainder of the year	25 c. a year.
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Climatological Data, monthly for 42 separate sections, each section 5 c. a copy	50 c. a year.
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Kite data; 1917, Mo. Wea. Rev. Supplements 10 and 11; 1918, Mo. Wea. Rev. Supplements Nos. 12, 13, 14, and 15	25c. each.
The daily weather map, with explanation (text and 4 charts)	5 c.
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Papers on Meteorology as a subject for study. (Reprinted from Dec., 1918, Mo. Wea. Rev.)	Free.
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Modern methods of protection against lightning. (Farmers' Bull. No. 842)	Free.
Convectional clouds induced by forest fires. (Reprinted from Mar., 1919, Mo. Wea. Rev.)	Free.
Weather forecasting in the United States	$1. 25
Weather forecasting and the structure of moving cyclones. (Reprinted from Feb., 1919, Mo. Wea. Rev.)	Free.
Periodical events and natural law as guides to agricultural research and practice. (Mo. Wea. Rev. Supplement No. 9)	25 c.
Notes on the climate of France and Belgium	Free.

As the surplus of MONTHLY WEATHER REVIEW, February and April, 1919, is limited, recipients who do not care to retain their copies will confer a favor by notifying the Chief of Bureau, who will arrange for the return postage.

FIG. 1.—Tornado at Norton, Kans., June 24, 1909. (From copyrighted photograph by C. E. Reed.)

MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

VOL. 47, NO. 7.
W. B. NO. 691.

JULY, 1919.

CLOSED SEPT. 4, 1919
ISSUED Oct. 6, 1919

CONTRIBUTIONS AND BIBLIOGRAPHY.

KANSAS TORNADOES.

By S. D. FLORA, Meteorologist.

[Dated: Weather Bureau, Topeka, Kans., Aug. 30, 1919.]

A tornado, frequently misnamed a cyclone, is the most spectacular of all storms known to inland America, and especially so in the prairie States, where the characteristic cloud can be plainly seen for miles. Its almost irresistible force is so terrifying and the damage and curious results of the enormous velocity of the whirling wind and sudden drop in pressure in the center of the vortex are so impressive that, once seen, they are never forgotten. Well-built houses explode and are carried away in small pieces, and stately shade trees that have sheltered families for generations are uprooted or have their limbs twisted off short as the whirling, writhing cloud descends from the sky and strikes them in its path, and yet perhaps a frail shanty within a few feet will escape without a board missing.

To the early settlers of Kansas, coming as they did from distant eastern States where such phenomena are almost unknown, these storms were one of the wonders of a new country to be told over and over to visitors and sent as special items of news to papers that gave them wide publicity. The result has been that the expression, "Kansas cyclone," has almost become an idiom of the language and the reputation of the State for visitations of these storms is greater than that of any other part of the country when, as a matter of fact, there is no reason to believe in the light of available data they are more numerous here, area considered, than in other States in this part of the country.

During the 33 years for which records of tornadoes in Kansas are available [1] 302 have been reported and of these only 9 per cent have occurred in the western third of the State, 41 per cent in the middle third, and 50 per cent in the eastern third. Just how far to the eastward this increase in frequency continues is a question that will require further investigation,[2] but it is interesting to see that the extreme western counties of the State enjoy comparative immunity and that it is possible western Missouri is more frequented by these storms than eastern Kansas.

Tornadoes have occurred in the State every month of the year, except January and December, but are most liable to occur in the late spring and early summer, since 50 per cent of the total number on record have been reported in May and June. Usually they come in the late afternoon, but they have been reported at practically all hours of the day.[1]

The meteorological conditions that precede a tornado are so well known that the term, "cyclone weather," has become a rather common expression in the State and refers to the oppressively warm, humid, or "sticky" weather that usually precedes them by several hours. A study of the weather maps indicates that these storms are most likely to form in the southeastern quadrant of a well-developed area of low pressure, but they have been reported in the northeastern and southwestern quadrants, so that hard and fast rules can not apply.

They may form after several hours of light wind or during a violent thunderstorm. Persons who have witnessed their formation usually report a great commotion in a threatening cloud or more commonly "two clouds came together." From this whirling mass the characteristic cloud descends until, in the case of the damaging storms, it touches the earth. Sometimes this cloud is really funnel shaped, more commonly it is described as resembling an elephant's trunk or a gigantic snake as it writhes and sways back and forth in its progress. Other observers have stated that it reminded them of a rope swinging back and forth from the clouds. Usually in case of a slender cloud the color is a milky white, except that near the ground it is dark from flying dust and débris. Clouds of larger diameter are generally of much darker shade.

It is not uncommon for two or more of these pendant clouds to be in evidence at the same time, sometimes in the formative stage, and as many as eight have been reported.[1] Often two will combine to form one of greater violence.

The noise of one of these storms as it approaches is terrific and has often been described as being "like that of a thousand railway trains crossing a trestle at the same time." It is probable the immense amount of destruction accomplished almost instantly as the whirling cloud passes over objects accounts for a great deal of this noise. Some observers have reported a peculiar humming noise like that of rapidly revolving machinery.

These storms cross the country at the rate of about 40 miles an hour, usually from the southwest, but there is no certainty about this. Occasionally one has been known to turn almost at right angles to its original course [2] and an instance has been reported where one moved back over the same path it had just traveled.[3]

[1] MONTHLY WEATHER REVIEW, December, 1915, 43: 615-617.
[2] The sparser population in western than in eastern Kansas may account in part for the difference in the numbers of tornados reported.—ED.

[1] Climatological Data, Kansas section, June, 1915.
[2] Climatological Data, Kansas section, April, 1916, and June, 1917.
[3] Climatological Data, Kansas section, June, 1919.

In an open country, which is characteristic of most o Kansas, a tornado cloud can be seen for miles and there is generally opportunity to take refuge when it occurs in the daytime. The most common and effective shelter is the far-famed "cyclone cellar," which is a cave near a residence, partially underground, with its top covered with soil and commonly used for dairy products and storing fruits and vegetables. Next in frequency of use for refuge is the southwest corner of the cellar or basement of a frame house. There are elements of danger in this, however, as, should the house be blown away, the cellar is likely to be partially filled with débris blown in with great violence. Instances have been reported where persons have survived by lying down in a ditch or shallow excavation, or simply on the lee side of a tree and locking the arms about it. In all these cases there is danger from flying pieces of timber or other objects with which the air is generally filled during such a storm; also a tree is likely to be uprooted if it is near the center of a storm path.

The freakish occurrences that result from these storms will tax the credulity of a person who has never seen them. Undoubtedly there is the usual tendency to exaggerate them, but after examining the wreckage a person is inclined to believe almost any story that is told. The often-recited instances of straws being blown with such violence they are left sticking in the bark and even in the wood of a tree or fence post have to be seen in order to be appreciated. Chickens are sometimes stripped of their feathers and left alive, though more often they are killed, if near enough the vortex of the cloud for that to happen. An instance has been related on creditable authority of a dresser being smashed to kindling and its mirror carried some distance and set down against a fence without being cracked; also of a window sash being blown from a railway depot, which was demolished, and laid down on an adjoining lawn with a heavy iron scale weight on it without the glass being broken. A glass jar of fruit from a shelf in this same depot was blown a considerable distance and picked up later in perfect condition. The writer has known of an instance where a well-built schoolhouse was torn into small pieces and large elm trees about it uprooted, yet a small coal shed among the trees and a short distance from the schoolhouse escaped with only one board missing. It is interesting to note that several people who had vainly tried to get into the schoolhouse for shelter from the storm had taken refuge in this coal shed and escaped uninjured. One of the remarkable features noted in reading over the accounts of these storms is the number of almost miraculous escapes. Unexplainable and almost unbelievable occurrences similar to the above that have come to the attention of the writer might be repeated at great length.

Tornado paths seem to be almost entirely independent of the topography of a country, popular opinion to the contrary notwithstanding. It is often said of a town which has never been visited by one that it owes its immunity to being in a valley, but the tornado of June 5, 1917,[1] crossed the Kansas River Valley a few miles above Topeka, mowing down trees on the steep slope of the high bluff as it descended into the south side of the valley and demolishing the little town of Elmont, which is on the lee side of a high bluff in the valley of Halfcreek.

Lightning is sometimes erroneously said never to strike twice in the same place, but this is certainly not true of a tornado. The little town of Codell, in Rooks County, Kans., in the western part of the State, was struck by a tornado on May 25 for three years in succession, each storm coming at approximately the same hour of the day.[1]

It is not at all unusual to find persons in Kansas who have been eyewitnesses of tornadoes, but photographs of the cloud are exceedingly rare. Usually one is so absorbed in watching the unusual sight or in getting to a place of safety that a camera is not thought of until it is too late. The views accompanying this article were collected by the writer in connection with an investigation of these storms in Kansas that has extended over a period of 12 years and the sources from which they have been received leave no doubt as to their authenticity.

[1] Climatological Data, Kansas section, July, 1917.

NOTE ON TORNADOES.*

In a "Note on Tornadoes," Lieut. J. Logie, aimed at showing that no convection currents are capable of producing tornadoes of the intensity claimed for some of these storms. The author computed the difference of temperature between the air in the center of the tornado and that outside. For a tornado having a pressure reduction of 50 millibars at the surface the mean temperature difference was found to be 23° A if the tornado extended to 5 km. (16,000 feet), 10° A if it extended to 10 km., and 5° A if it extended to 15 km. From the known values of the lapse rate of saturated air, it follows that under conditions of maximum instability a saturated ascending current not less than 8 km. high might produce a tornado of this intensity. Since such instability rarely occurs, and in addition ascending currents of saturated air are usually everywhere penetrated by descending masses of cooler air, even a tornado of this intensity is unlikely to be so produced in natural conditions.—*Symons's Metl. Mag., July, 1919, p. 67.*

A LOCAL STORM AT ABERDEEN PROVING GROUND, MD., JULY 6, 1919.

By OTTO NEUMER.

The hot spell of early July came to a close at Aberdeen, Md., with a thunderstorm marked by heavy rainfall, and high winds which wrecked a Handley-Page aeroplane standing on the aviation field. The maximum temperature for the 3d was 93°F.; the 4th, 94°F.; and the 5th, 94°F. The minima were successively 59°F, 66°F, 69°F., and 72°F., the last being in the night of the 5th and 6th. During the 5th and 6th of July, the surface winds were southeast, very warm and moist. At 2:15 p. m. (75th meridian time) of the 5th there was a west wind at an altitude of 3,000 meters. On Sunday morning, the 6th, the surface wind was southeast, but veered rapidly with altitude until at 1,700 meters it was coming from the west. These west winds aloft were probably potentially colder than those at the surface, and in passing over the warm southerly winds formed a decided temperature gradient.

Cumulus clouds developed on the morning of the 6th, and early in the afternoon covered about half the sky. The sun became obscured at 2:25. At 3:30 p. m. the wind suddenly veered from south to west, backing to southwest at 4:40 p. m. and rising from 8.5 to 30 miles per hour. At the same time the sky became overcast with heavy stratus clouds. Rain began falling at 4:43, the temperature suddenly dropped from 82°F. to 65°F., and

[1] Climatological Data, Kansas section, July, 1919.
* Roy. Meterological Soc., June 18, 1919.

FIG. 2.—Tornado cloud at Solomon, Kans.

[To face p. 448.]

FIG. 3.—Tornado cloud at Minneapolis, Kans., 1900. (Camera pointing to northeast.)

FIG. 4.—Tornado cloud at Ellis, Kans., June, 1915. (The color of the cloud as printed is deceptive. The original photograph shows it was quite dark.)

FIG. 5.—Tornado cloud at Mullinville, Kans., June 11, 1915.

[To face p. 448]

FIG. 6.—Tornado cloud at Hoyt, Kans., April 19, 1916.

FIG. 7.—Tornado cloud at Lebanon, Kans., Oct. 9, 1913. (Photographed by Earl V. Bower.)

FIG. 8.—Tornado cloud at Lebanon, Kans., Oct. 9, 1913. (Photographed by Earl V. Bower.)

[To face p. 448.]

FIG. 9.—Tornado cloud at Lebanon, Kans., Oct. 9, 1913. (Photographed by Earl V. Bower.)

the relative humidity rose rapidly from 63 to 98. The barograph recorded an abrupt rise in pressure from 29.55 inches to 29.63 inches, and continued to rise uniformly thereafter, attaining a pressure of 29.80 inches at 8:00 a. m., July 7. In the midst of the heaviest rainfall the wind attained a maximum velocity of 40 miles per hour at 4:50 p. m., at which time the wind backed from southwest to southeast, indicating that the center of the storm had passed probably on the south, since the squall wind usually blows out from the region of heaviest rainfall. Three minutes later, the wind veered to northwest from which direction it continued to blow for several hours after normal conditions were again restored. The rainfall during the first 17 minutes was 1.03 inches, of which 0.77 inch fell between 4:45 and 4:55 p. m. The rain continued till 5:30, giving a total of 1.24 inches for the storm. Other thunderstorms occurred in eastern Pennsylvania, New Jersey, and New York, but no rain fell at Baltimore or Washington.

The surface wind July 7 at 7:00 a. m. was north and at 1,100 meters northeast; conditions associated with an extensive HIGH over the Great Lakes.

PRELIMINARY MEETING OF OFFICIAL WEATHER BUREAU DIRECTORS AT LONDON, JULY 3–9, 1919.

By Dr. L. A. BAUER.

Department of Terrestrial Magnatism, Carnegie Institution of Washington.

[Dated Sept. 1, 1919.]

At the call of Sir Napier Shaw, the president of the prewar International Meteorological Committee, there was recently held in the Meteorological Office, London, from July 3–9, a preliminary meeting of such of the official weather bureau directors who could attend at short notice and who represented the allied and neutral countries. The prime purpose of the meeting was to reach some preliminary agreements, in advance of the proposed Paris Meteorological Conference meeting at the end of September, regarding official meteorological matters and interchange of data.

There were present Sir Napier Shaw, chairman, A. Angot (France), Lieut. Col. E. Gold, of the Meteorological Office, who served as secretary, E. Van Everdingen (Holland), Lieut. H. D. Grant (British Admiralty Meteorological Office), Th. Hesselberg (Norway), L. Palazzo (Italy), Capt. C. Ryder (Denmark), G. T. Walker (India), A. Wallén (Sweden), and L. A. Bauer, representing C. F. Marvin (United States).

The signal success of the meeting was due chiefly to Sir Napier, under whose tactful and skillful management decisions on many matters were put in form for submission to the coming Meteorological Conference at Paris. Entire harmony prevailed throughout the deliberations, the representatives of the various countries having free and cordial intercourse with one another.

Among the pleasant social events may be mentioned the visit to the Kew Observatory on the afternoon of July 3, and reception in the evening at the Meteorological Office; dinner tendered by the Meteorological Office at Bailey's Hotel, July 7; visit to W. H. Dines' observatory at Benson, July 8.

MEETING OF INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS AT BRUSSELS, JULY 18–28, 1919.*

By Dr. L. A. BAUER.

Director, Department of Terrestrial Magnetism, Carnegie Institution of Washington.

[Dated Washington, Sept. 1, 1919.]

Under the auspices of the International Research Council there was established at Brussels, during the meeting of the Council in the Palais des Academies, July 18–28, 1919, various unions on Astronomy, Mathematics, Physics, Chemistry, Geodesy and Geophysics, and Scientific Radiotelegraphy.

The various countries, formerly at war with the Central Powers, were, in general, fully represented by officially appointed delegates. At the last session of the Council a resolution was passed respecting the entrance of other countries and the invitations to be extended to them.

The International Union of Geodesy and Geophysics, as finally established for a period of 12 years beginning on January 1, 1920, consists of the following sections:

(*a*) *Geodesy:* William Bowie (United States), president; Vicenzo Reina (Italy), vice president; Lieut. Col. Perrier (France), secretary and director of Central Bureau.

(*b*) *Seismology:* Owing to continuation of present agreement among countries with regard to the International Seismological Association, which is to continue for some time longer, it was not possible to organize this section definitely.

(*c*) *Meteorology:* Sir Napier Shaw, president; A. Angot, vice president; C. F. Marvin, secretary and director of Central Bureau.

(*d*) *Terrestrial Magnetism and Electricity:* A. Tanakadate (Japan), president; C. Chree (England), vice president; L. A. Bauer (United States), secretary and director of Central Bureau.

(*e*) *Physical Geography:* Naming of president deferred until entrance of neutral countries; H. Lamb (England), vice president; G. P. Magrini (Italy), secretary and director of Central Bureau; Sir Charles Close (England), and Mr. G. W. Littlehales (United States) were made members of the executive committee, in addition to president, vice president, and secretary.

(*f*) *Volcanology:* Prof. A. Riccò (Italy), president; H. S. Washington (United States), vice president; Dr. A. Malladra (Italy), secretary and director of Central Bureau.

The following officers of the Union were chosen: Charles Lallemand (France), president; Col. H. G. Lyons (England), general secretary; the presidents of the various sections are the vice presidents of the Union.

The opinion was expressed generally that in the *organization of work* for the various sections the endeavor should be to distribute the work among various committees rather than centralize the investigational work at the Central Bureaus.

At a preliminary meeting of the section on Meteorology, under the chairmanship of Col. Lyons, in the absence of Sir Napier Shaw, a brief discussion was held with regard to the work of the section. The general opinion was that

* A more detailed account is published in *Nature* (London), Aug. 14, 1919, pp. 464–466 (summarized in *Science*, Sept. 5, 1919, p. 226). A full account of the organization of the American section of this International Union of Geodesy and Geophysics is given in *Science*, Sept. 5, and 12, 1919, pp. 233–238, 255–259.

as the Meteorological Committee of Weather Bureaus must necessarily concern itself primarily with official and administrative matters, there would be abundant opportunity for useful work of the sections along broad investigational lines. Two general resolutions to the following effect were passed:

"That there be appointed a joint committee of the International Union of Astronomy and of the section of Meteorology of the International Geophysical Union for investigational work on solar radiation."

"That there be appointed a joint committee of the sections of Terrestrial Magnetism and Electricity, and of Meteorology, of the International Geophysical Union, for international work in atmospheric electricity."

The success of the meetings of the International Research Council and of the affiliated International Unions was, in no small measure, due to the indefatigable labors of Monsieur G. Lecointe, the well-known director of the Belgian Royal Observatory at Uccle, who had charge of the local arrangements. He was reelected a member of the Executive Committee of the Council and also one of the five vice presidents of the International Astronomical Union. On Saturday afternoon, July 26, in response to M. Lecointe's invitation, the astronomers and geophysicists visited the Uccle astronomical and geophysical observatories and were later entertained at the director's home.

STEREOSCOPIC REPRESENTATION OF WIND MOVEMENT ALOFT.

By R. C. LANE and R. A. WELLS, Observers.

[Dated: Weather Bureau, Washington, Aug. 30, 1919.]

Prior to May, 1919, winds aloft had been represented by a series of charts, as explained in the MONTHLY WEATHER REVIEW, April, 1919, page 219, and figure 3, page 220. A separate map was constructed for each level for which a summary of the weather conditions was desired.

While that system of mapping is excellent to show a summary of the wind direction and velocity for any one level, it is inadequate for the busy forecaster. The data being distributed over six or eight maps are confusing when viewed as a whole, and it is equally difficult mentally to summarize the wind conditions aloft as set forth by such a series of maps in order to determine the turning of the wind aloft.

It was suggested by Maj. E. H. Bowie, Supervising Forecaster, that maps be prepared by piling arrows upon a post, the posts to be located upon a base-map indicating the location of each station, and the entire map to be photographed with a stereoscopic camera. The finished prints could be mounted upon cards and viewed through a stereoscope.

After a brief period of experimentation the present method was developed. Now, three elements may be represented on a single map, namely, wind direction, wind speed, and altitude above the surface of the earth.

Wind direction is represented to the nearest one of the 16 compass points, by setting the arrows, observing the top and bottom of the map as north and south, respectively. Wind speed or velocity is represented by the relative character on the head of the arrow. The principal characters used are the numerals from 0 to 8, inclusive, the relative values of which are given in the following table, in meters per second.

Scale of velocities for wind aloft map.

Arrow character.	Representative value.	Arrow character.	Representative value.
0	Calm, less than 1 m/s.	7	27 to 33 m/s.
1	1 to 3 m/s.	8	Above 34 m/s.
2	4 to 6 m/s.	M	Data missing.
3	7 to 10 m/s.	C	Low clouds.
4	11 to 15 m/s.	R	Raining.
5	16 to 20 m/s.	S	Snowing.
6	21 to 26 m/s.		

Altitude is represented by the length of the arrow and the position of the arrow on the post as set forth by the stereoscopic view. The longest arrow represents the surface, while the graduated shorter lengths represent, in meters, 250, 500, 1,000, 1,500, 2,000, 3,000, and 4,000, respectively, the length of the arrow decreasing with increase in altitude.

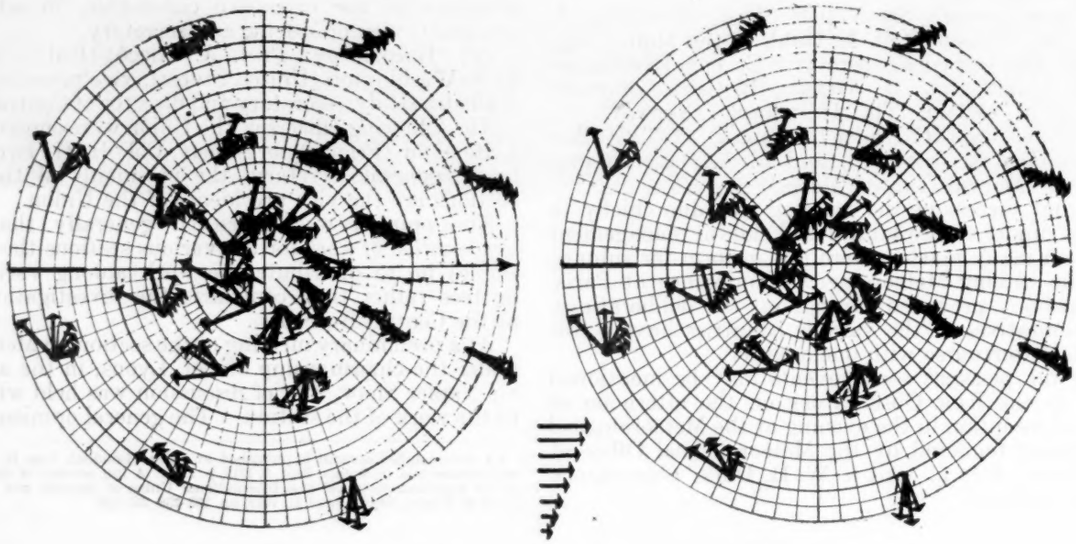

Fig. 1.—Average wind circulation aloft about HIGHS, as determined by W. R. Blair, at Mount Weather, Va. (Longest arrow, surface at 526 m.; next, 1,000 m.; shortest, 7,000 m.)

[To face page 450.]

Note.—These plates may be cut out and viewed through a stereoscope.

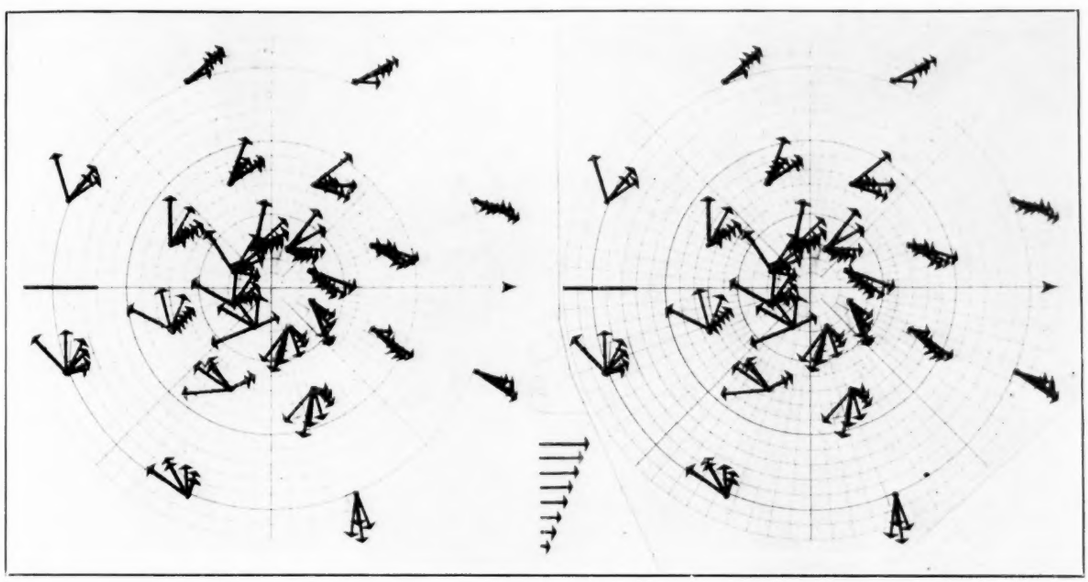

Fig. 1.—Average wind circulation aloft about HIGHS, as determined by W. R. Blair, at Mount Weather, Va. (Longest arrow, surface at 526 m.; next, 1,000 m.; shortest, 7,000 m.)

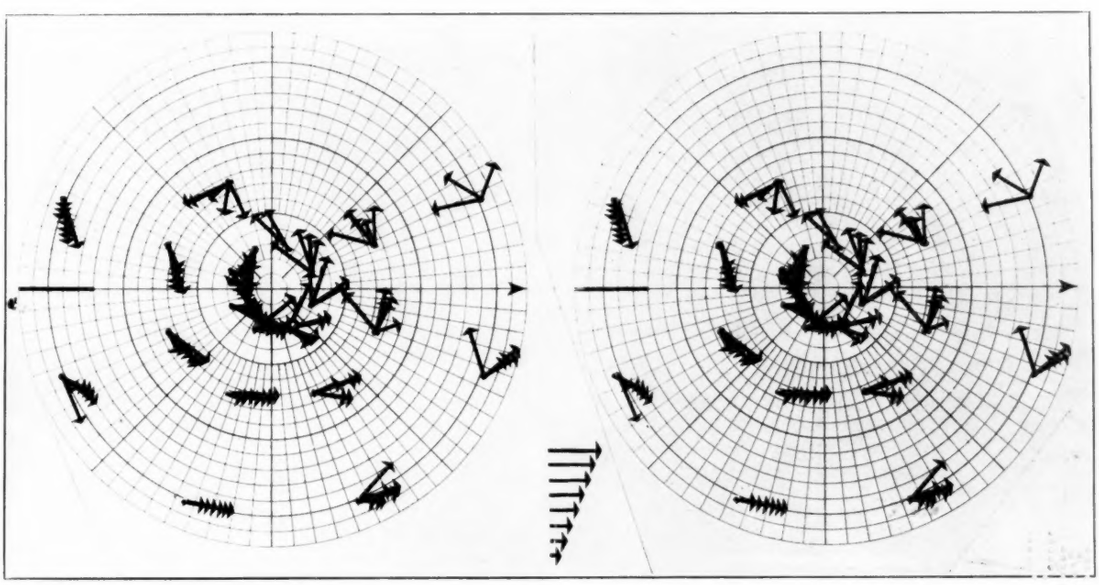

Fig. 2.—Average wind circulation aloft about LOWS, as determined by W. R. Blair, at Mount Weather, Va. (Longest arrow, surface at 526 m.; next, 1,000 m.; shortest, 7,000 m.)

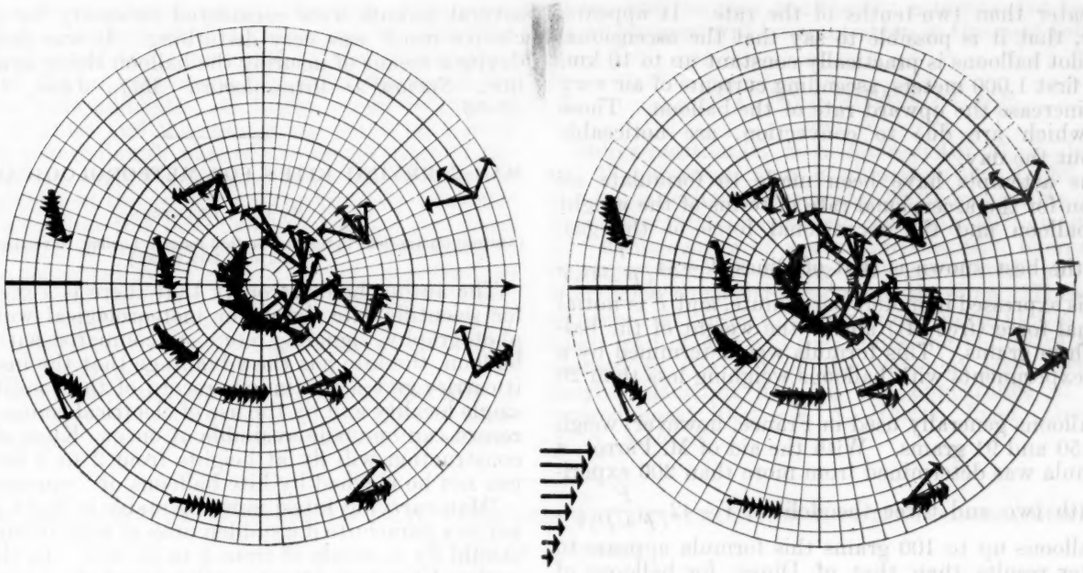

FIG. 2.—Average wind circulation aloft about LOWS, as determined by W. R. Blair, at Mount Weather, Va. (Longest arrow, surface at 526 m.; next, 1,000 m.; shortest, 7,000 m.)

The data from which the map is constructed are collected daily from the pilot balloon observation stations by telegraph. The posts are built up from the data and set in their relative positions, each post showing the wind conditions aloft for that particular station. From a distance of 10 feet away and perpendicular to the surface of the map a photographic exposure is made with a stereoscopic camera.

The object of using a stereoscopic camera is to set the flat map and superimposed arrows out in relief. For this work the stereoscopic camera has been replaced by one such as that the commercial photographer uses. Then, two separate exposures, one, 7½ inches to the right and the second 7½ inches to the left of the center of the map, are made. The principle is the same as that of the stereoscopic camera, but the results are far more satisfactory.

This system of upper air mapping with slight modification has been applied to "Means of wind observation in HIGHS and LOWS at Mount Weather. Blair—five-year summary, 1907 to 1912." Descriptions and explanations of the base figures have already been given in the Bulletin of Mount Weather Observatory, page 125, under "Wind direction at the different levels in relation to surface air pressure." Also in Report No. 13, Meteorology and Aeronautics, page 37, under "Wind change with height in LOWS."

Since wind velocities are not available for this summary, only the wind direction with altitudes could be represented; therefore, arrows with no designation of velocity were used.

Figure 1 represents average wind circulation aloft about HIGHS, and figure 2 represents average wind circulation aloft about LOWS, as determined from "Blair's Five-Year Summary of Mount Weather." If the accompanying figures are cut out and mounted, as printed, upon cards, they will be suitably arranged for study with the stereoscope. The arrows fly with the wind, and the length of the arrow decreases with increase in altitude.

THE ASCENSIONAL RATE OF PILOT BALLOONS.

By J. ROUCH.

[Translation and abstract from Comptes Rendus, Paris Acad., July 15, 1919, pp. 83–85

Aerological investigations carried on by the single theodolite method are dependent upon the assumption that the rate of ascent of a small rubber balloon filled with hydrogen is constant. During the war a great many experiments were made to verify and determine ascensional rates, a well as verify the fact that the rate of ascent is a function of the weight of the balloon and the ascensional force at the time the balloon is released.

Using rubber balloons, weighing 50 grams and given an ascensional force of 150 grams, 168 pilot-balloon flights were made by the two-theodolite method. The mean ascensional rate observed was 188 meters per minute.

The following table gives, for successive altitudes of 1,000 meters, the mean ascensional rate in meters per minute, together with the amounts of variation from the mean in each layer.

From—	To—	Number of observations.	Mean ascensional rate.	Amount of variation.			
				Less than one-tenth.	Between one-tenth and two-tenths.	Between two-tenths and three-tenths.	More than three-tenths.
Meters.	*Meters.*		*Min.*				
0	1,000	168	198	98	46	14	10
1,000	2,000	164	184	141	21	1	1
2,000	3,000	122	184	105	16	1	0
3,000	4,000	71	186	60	10	1	0
4,000	5,000	28	186	22	4	1	1
5,000	6,000	11	188	11	0	0	0
6,000	7,000	9	190	7	2	0	0
7,000	8,000	4	196	4	0	0	0
8,000	9,000	3	198	3	0	0	0
9,000	10,000	2	194	2	0	0	0

Notwithstanding the fact that above 6,000 meters the number of observations is very small, there were no varia-

tions greater than two-tenths of the rate. It appears, therefore, that it is possible to say that the ascensional rate of pilot balloons is practically constant up to 10 km.

In the first 1,000 meters, ascending currents of air very sensibly increase the upward rate of the balloon. These effects, which are due to convection, are noticeable throughout the day.

Various attempts have been made to formulate an expression for the ascensional rate in terms of the weight of the balloon and the ascensional force of the gas. Perhaps the best known is that of Dines, $V=84\frac{F^{\frac{1}{3}}}{(F+P)^{\frac{1}{3}}}$, where V is expressed in meters per minute, and F is initial ascensional force (free-lift) and P the weight of the balloon, both in grams. This formula was determined by a series of experiments with balloons weighing less than 20 grams.

The balloons generally used in France, however, weigh between 50 and 91 grams. With the aid of M. Parrot, a new formula was determined from more than 200 experiments with two and three theodolites, $V=42\frac{F}{(F+P)^{\frac{1}{3}}}$.

For balloons up to 100 grams this formula appears to give better results than that of Dines; for balloons of greater weight, however, a new series of experiments should be made.—*C. L. M.*

FURTHER MEASUREMENTS ON THE RATE OF ASCENT OF PILOT BALLOONS.[1]

By J. S. DINES.

Experiments were made in the Albert Hall, in which a clear height of 40 meters is available from floor level to the grid at the center of the domed roof. The formula in general use for the rate of ascent is, rising velocity, $V=q.\sqrt{L}/\sqrt[3]{(W+L)}$, where $L=$ the free lift and W the dead weight of the balloon and q is a constant the value of which has to be determined under different conditions. It had been suggested that the value of q varied with different degrees of loading of the balloon. Attention was directed to this question and quantitative results obtained. Measurements were also made with a candle lantern of the pattern used for night ascents hung below the balloon. It was found that this produced no effect upon q. In timing the rate of ascent in closed buildings a fine thread has generally been attached to the neck and has been drawn up from the floor as the ascent proceeded. In the present case experiments which were made with and without such a thread showed that some correction is necessary where a thread is used. The general results confirmed the value $q=84$, which is used at the present time, for balloons of the size generally adopted for pilot balloon work. This value gives velocities in meters per minute when lift and dead-weight are expressed in grams.

In the discussion which followed Lieut. Col. Gold said that a considerable difference might exist between the rates of ascent in the open air and in a closed room. It would be of advantage if experiments could be conducted alongside the Eiffel Tower (300 meters high) with observers stationed on each platform. He carried out experiments with two theodolites in France, and the resulting rates of ascent varied from 100 to 300 meters per minute. Sir Napier Shaw thought the fact that several ascents were considered necessary for any conclusive result was very disturbing. It was desirable to devise a means of insuring the balloon rising in a straight line.—*Symons's Meteorological Mag., June, 1919, pp. 55–56.*

[1] Abstract of paper presented on May 21, 1919, before the Royal Meteorological Society, London.

MAN-CARRYING KITES FOR METEOROLOGICAL WORK.[1]

By L. P. FRANTZEN.

[Abstract from reviews in the Aeronautical Journal, London, November, 1918, p. 382, and May, 1919, p. 286.]

The author holds strongly that there is a great future for scientific kite flying for meteorological work, aerial photography, signaling, etc. As compared with the free balloon, the kite has the advantage that the instruments it carries give a continuous record of the conditions in a single locality and by the use of electrical connections the record can be made available at once. Kites of suitable construction will fly at heights from 2 to 3 kms. which can not be reached by kite balloons or "sausages."

[Man-carrying kites] must be stable in flight, and must act as a parachute if a sudden drop of wind occurs. They should fly in winds of from 5 to 25 m/s. In the scheme outlined for man-lifting a pilot kite is first sent up and the train of lifting kites attached to the cable at intervals of 10 to 30 meters. A basket traveling up the cable is used for the observer. The winch is preferably mounted on a lorry with separate motors for winding in the cable and driving the lorry. A dozen men have been found to be sufficient to manipulate a train of man-lifting kites. Sketches show several suggested forms of kites, both of the monoplane and box types. Details of construction are also shown.

[1] L'Aérophile, Sept. 1–15, 1918, and especially "L'Avenir des Planeurs Captifs," L'Aérophile, Jan. 1–15, 1919, pp. 21–24.

THE STATIC CONDITION OF THE ATMOSPHERE.

By Dr. R. S. WOODWARD,

President, Carnegie Institution of Washington.

[Abstract of remarks made June 24, 1919, on the occasion of a joint meeting of the American Sections of Astronomy and Geophysics of the International Geophysical Union.]

Although the atmosphere is the special province of meteorologists it bears highly important relations to the sciences of astronomy and geodesy and sustains highly important relations also to the secular phenomena of geology. Visualizing the atmosphere in its entirety, it appears somewhat anomalous that the kinetic properties of that portion with which meteorology has been hitherto chiefly concerned have been more completely determined than the apparently simpler statical properties.

Of these latter, two are conspicuously outstanding, to wit, the mass distribution and the total mass of the atmosphere. Assuming that the atmosphere is a fluid and that it may have a boundary similar to the upper surface of the ocean, Laplace showed that the atmosphere is limited by a lenticular envelope symmetrical with respect to the polar axis of the earth and extending to a distance of about 17,000 miles at the poles, and to a distance of about 26,000 miles at the equator. But more recent investigations indicate with a considerable degree of probability that the atmosphere has no such limiting fluid surface. More recent investigations have indicated also that the total mass of the atmosphere is not constant but that it undergoes more or less continual exchanges

with the gases of external space. Similarly, little progress has been made toward a determination since the time of Laplace of the total mass of the atmosphere. If the earth did not rotate and if the distribution of the atmosphere were adiabatic, its height would be limited to about 17 miles and the total mass would be a little more than one-millionth part of the entire mass of the earth. But the earth rotates and while the distribution near the surface of the oceans is approximately adiabatic it is probable that this law does not hold at any great height. Hence, if we suppose the mass distribution to be such as conceived by Laplace, the total mass must be much larger than the lower limit just assigned. Here, then, are two capital problems available for research by aid of the more recently acquired resources of knowledge concerning the constitution of gases.

Recent researches, and especially those of Bjerknes in his Dynamic Meteorology, have gone far toward a rational treatment of the kinetic properties of the atmosphere, and we may confidently entertain the hope that rapid progress will be practicable in the near future.

NOTE ON A MIRAGE AT SEA.

[Dated July 3, 1919.]

Ship's position [U. S. S. *Radnor*] 40° 26′ N., longitude 64° W., apparent time of ship, 4 p. m. Light easterly winds, smooth sea, barometer 29.94 inches; my personal barometer, 30.00 inches; air, wet bulb, 59°; air, dry bulb, 63°; temperature of sea at surface, 53°; overcast with cumulus clouds. Strong mirages noted all around. Four other ships were in sight at the time. These vessels appeared at times to be steaming along at the top of a hugh wall of ice; at other times the bodies of the ship seemed to rise out of the water at least twice their height. Horizon had all the appearance of a long, rugged coast line.—*M. S. Harloe, Lieut. Commander, U. S. N. R. F.*

THE SUN'S INFLUENCE ON THE DIURNAL VARIATION OF THE ATMOSPHERIC POTENTIAL-GRADIENT.[1]

By W. F. G. SWANN.

Professor of Physics, University of Minnesota.

[Dated Minneapolis, Minn., July 10, 1919.]

SYNOPSIS.—The paper presents a view as to a possible origin of part of the diurnal variation of the atmospheric potential-gradient.

Various phenomena in cosmical physics lend support to the view that the upper atmosphere is so highly conducting as compared with the air near the earth's surface that, for electrostatic considerations, it may be looked upon as perfectly conducting. Thus, for example, we may look upon all points on a sphere in the upper atmosphere, concentric with the earth, as being at the same potential.

If the conductivity of the atmosphere depended only upon the altitude, and were independent of the position on the earth's surface with respect to the sun, the surfaces of equal conductivity would be spheres concentric with the earth, and the conduction current-density and potential-gradient would be independent of the position on the earth's surface. If the sun emits an ionizing radiation, however, we may expect the surfaces of equal conductivity to be dented inward toward the earth when the sun is at the zenith. Thus, the total resistance of a column of air of unit cross section, extending from the earth's surface to a given altitude in the upper atmosphere, would be least when the sun was at the zenith. It would result that the atmospheric conduction current-density would be greatest when the sun was at the zenith; and, if the conductivity of the air at the surface of the earth were the same at all places, we should have a higher potential-gradient on the sunlit portions of the earth than on those remote from the sun.

The ideas contained in the above outline are illustrated in the second portion of the paper by an example which is worked out mathematically. The bearing of these considerations upon the effect of an eclipse on the potential-gradient is also discussed.

Various phenomena in cosmical physics lend support to the view that the upper atmosphere is highly conducting as compared with the air near the earth. Thus, for example, Schuster has developed a theory of the diurnal variations[2] of terrestrial magnetism which invokes, among its requirements, a conductivity about 3×10^{11} times as great as that at the earth's surface. Such a value appears by no means unreasonable when viewed in the light of our beliefs as to the processes at work in the upper atmosphere. The sun's ultra-violet light alone, although insufficient to account for a conductivity of the order of magnitude required by Schuster's theory is able, as the writer has shown,[2] to account for a magnitude one thousandth of this amount, i. e., a conductivity so high that a column of air extending one-fourth of the way around the earth in the upper atmosphere would offer no more resistance than would a column of surface air of equal cross section, but only 3 cms. long.

If the upper atmosphere has a conductivity approximating even to that which the ultra-violet light is capable of accounting for in the sunlit regions, it may, for most electrostatic purposes, be considered as a perfect conductor.

If two concentric spheres be maintained at a difference of potential, the field at the surface of the inner sphere will, from symmetry, be the same at all points of the surface. If a dent be made in the outer sphere, the distance between the spheres at this point will be decreased, and, since each sphere is at the same potential all over, the field at the surface of the inner sphere, under the dent, will be stronger than that elsewhere. Or if, instead of making a dent in the outer sphere we fill the space between the spheres with a medium which is slightly conducting, and in which the conductivity is the same at all points except that at one place it increases from its normal value as we go from the inner to the outer sphere, then the current density will be greater at this place than elsewhere, and the potential-gradient at the surface of the inner sphere will be greater here than elsewhere.

The above crude illustration suggests that if the upper atmosphere is in a highly conducting state, but the conductivity mounts more rapidly with altitude on the sunlit side than on the side more remote from the sun, the potential-gradient should be higher in the former case than in the latter. Here, then, would be an influence playing a part in the determination of the diurnal variation of the potential-gradient, and of such a type as to predict a maximum of the potential-gradient by day and a minimum by night.

On a view of this kind the air-earth conduction current-density at the earth's surface should go through a diurnal variation of the same kind as the potential-gradient, unless the surface conductivity also varies throughout the day. Actual observations bring out the fact that, as a general rule, the conductivity at the earth's surface varies in the opposite sense to the potential-gradient, and in such a way as to maintain the product of the two (the air-earth current-density) more nearly independent of the time of day than either of its constituent factors. The general nature of the phenomena is such as to suggest that the quantity fundamentally determined is the air-

[1] Read before the May meeting of the Mathematical Association of America.
[2] Terr. Mag., v. 21, pp. 1–8, 1916.

earth current-density and that the diurnal variation of the potential-gradient is the direct outcome of the automatic adjustment of the electric field of the atmosphere to maintain constancy in the air-earth current-density while the conductivity suffers a diurnal variation. However, it is by no means universally true that the conduction current-density remains even approximately constant. Thus, for example, if we take the observations for potential-gradient and ionic-content obtained over the ocean on the fourth cruise of the yacht *Carnegie*,[1] by Messrs. H. F. Johnston, B. Jones, I. A. Luke, and S. J. Mauchly, using the apparatus designed by the writer, and if we assume the air-earth current-density to be proportional to the product of the ionic-content and potential-gradient, we obtain a curve such as figure 1, showing a maximum at 9 a. m. and a smaller maximum at midnight.

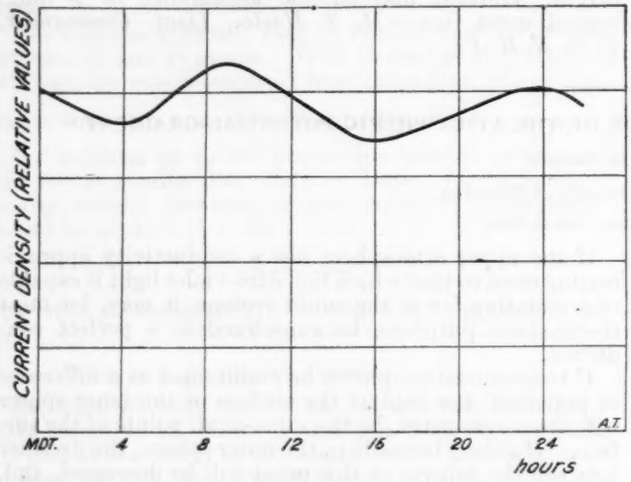

FIG. 1.

It thus appears, at any rate, worth while to consider in rather greater detail possibilities such as that suggested at the beginning of this article for explaining at any rate a portion of the diurnal variation of the potential-gradient otherwise than as a mere secondary effect resulting from a diurnal variation of the conductivity in the immediate vicinity of the earth, and to this end we shall work out an illustrative example.

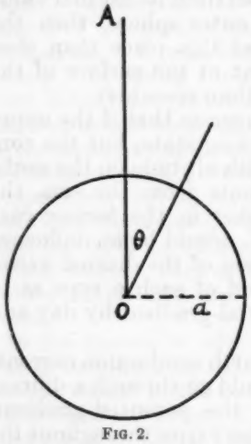

FIG. 2.

The problem to be considered may be specified as follows: Let OA (fig. 2) represent the direction of the sun, the circle of radius a representing the earth. We may assign a conductivity increasing with altitude to a very high value according to some prescribed law of such a kind as to correspond to a more rapid increase in the sunlit portions of the atmosphere than elsewhere, and we may calculate the distribution of potential-gradient in the atmosphere, and in particular over the earth's surface. Or we may state the problem to be solved in the converse manner: Assign a variation of potential-gradient over the earth's surface and determine a conductivity which shall increase to a very high value with altitude, and shall have such a distribution as shall correspond to the assigned distribution of potential-gradient over the earth's surface.

If σ is the conductivity, the equation of continuity takes the form:

$$\frac{\partial}{\partial r}\left(\sigma r^2 \frac{\partial V}{\partial r}\right)+\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sigma \sin\theta \frac{\partial V}{\partial\theta}\right) \quad (1)$$

A limited class of solutions, but one which will fit our purpose, is one in which the current density is derivable from a potential ψ, so that

$$\frac{\partial\psi}{\partial r}=\sigma\frac{\partial V}{\partial r}, \qquad \frac{\partial\psi}{\partial\theta}=\sigma\frac{\partial V}{\partial\theta} \quad (2)$$

Under these conditions, equation (1) becomes:

$$\frac{\partial}{\partial r}\left(r^2\frac{\partial\psi}{\partial r}\right)+\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial V}{\partial\theta}\right)=0 \quad (3)$$

which is La Place's equation.

Equations (2) lead immediately to:

$$d\psi=\sigma dV \quad (4)$$

Moreover, since ψ and V are perfect differentials, equations (2) lead to

$$\frac{\partial V}{\partial r}\cdot\frac{\partial\sigma}{\partial\theta}-\frac{\partial V}{\partial\theta}\cdot\frac{\partial\sigma}{\partial r}=0 \quad (5)$$

Solving these equations by La Grange's method, the subsidiary equations become

$$\frac{dr}{\left(\frac{\partial\sigma}{\partial\theta}\right)}=\frac{-d\theta}{\left(\frac{\partial\sigma}{\partial r}\right)}=\frac{dV}{0} \quad (6)$$

The solution of the first of these two is $(\sigma-\text{const.})=0$, and the second equation requires that $z=\text{const.}$ Hence, the solution of (5) is $V=\phi(\sigma)$, where ϕ is an arbitrary function.

Hence, from (4), ψ is a function of σ. Thus both σ and V are functions of ψ.

Thus, if ψ be chosen as a solution of La Place's equation, and σ be taken as a function of ψ, the corresponding expression for V will be given by:

$$\frac{dV}{d\psi}=\frac{1}{\sigma} \quad (7)$$

The restriction that the currents shall be derivable from a potential ψ thus limits us to problems where σ is constant when V is constant, and where σ is expressible as a function of ψ, which is itself a solution of La Place's equation.

Let us now suppose that $V=0$ when $r=a$, i. e., $\psi=$ const. when $r=a$, since V is a function of ψ. This will automatically necessitate the condition $\sigma=$constant (say σ_0) when $r=a$, since σ is a function of ψ. Let us further suppose that, when $r=a$, $\left(\frac{\partial V}{\partial r}\right)$ is some assigned function of θ which we shall imagine expanded in a series of Legendre coefficients in the form:

$$\left(\frac{\partial V}{\partial r}\right)_{r=a}=A_0+A_1P_1(\mu)+A_2P_2(\mu)+\cdots \text{ etc.} \quad (8)$$

where $\mu=\cos\theta$.

From (2) we have,

$$\left(\frac{\partial\psi}{\partial r}\right)_{r=a}=\sigma_0A_0+\sigma_0A_1P_1(\mu)+\sigma_0A_2P_2(\mu)+\cdots \text{ etc.} \quad (9)$$

[1] Publication No. 175 (Vol. III) of the Carnegie Institution of Washington, p. 417.

But, since ψ is a solution of La Place's equation, it must be of the form:

$$\psi = \frac{a_0}{r} + \left(a_1 r + \frac{1}{r^2}\right) P_1(\mu) + \cdots \left(a_n r^n + \frac{b_n}{r^{n+1}}\right) P_n(\mu) \cdots$$

and

$$\left(\frac{\partial \psi}{\partial r}\right)_{r=a} = -\frac{a_0}{a^2} + \left(a_1 - \frac{2b_1}{a^3}\right) P_1(\mu) + \cdots \left[n a_n a^{n-1} - \frac{(n+1) b_n}{a^{n+2}}\right] P_n(\mu) \tag{10}$$

Hence, from (9) and (10),

$$n a_n - \frac{(n+1) b_n}{a^{2n+1}} = \frac{\sigma_0 A_n}{a^{n-1}} \tag{11}$$

Again, since $\psi = \text{const.}$ when $r = a$, we have:

$$a_n + \frac{b_n}{a^{2n+1}} = 0 \tag{12}$$

(11) and (12) serve to determine a_n and b_n in terms of A_n, and we finally have

$$\psi = -\frac{\sigma_0 A_0 a^2}{r} + \frac{\sigma_0 A_1}{3}\left(r - \frac{a^3}{r^2}\right) P_1(\mu) + \cdots + \frac{\sigma_0 A_n}{2n+1}\left[\frac{r^n}{a^{n-1}} - \frac{a^{n+2}}{r^{n+1}}\right] P_n(\mu) + \cdots \tag{13}$$

If σ be taken as any function of ψ, and V be determined from (7), these values of σ and V will be consistent with the distribution of potential-gradient given by (8).

As an example, let us suppose that, when $r = a$,

$$\left(\frac{\partial V}{\partial r}\right)_{r=a} = X_0 + X_0 \alpha (1 + \cos\theta) \tag{14}$$

where α is a constant.

This is of the form (8), where $X_0(1+\alpha) = A_0$, and $X_0 \alpha = A_1$, so that

$$\frac{\psi}{a} = -\sigma_0 X_0 (1+\alpha)\frac{a}{r} + \frac{\sigma_0 X_0 \alpha}{3}\left(\frac{r}{a} - \frac{a^2}{r^2}\right)\cos\theta + \cdots \tag{15}$$

Now choose σ of the form:

$$\sigma = \sigma_0 e^{\beta\left[1 - \left\{\frac{a}{r} - \frac{\alpha}{3(1+\alpha)}\left(\frac{r}{a} - \frac{a^2}{r^2}\right)\cos\theta\right\}\right]} \tag{16}$$

where β is a constant.

This value of σ is a function of ψ, and reduces to σ_0 when $r = a$. From (2) and (16) we have:

$$\frac{\partial V}{\partial r} = X_0\left[(1+\alpha)\frac{a^2}{r^2} + \frac{\alpha}{3}\left(1 + \frac{2a^3}{r^3}\right)\cos\theta\right] e^{-\beta\left[1 - \left\{\frac{a}{r} - \frac{\alpha}{3(1+\alpha)}\left(\frac{r}{a} - \frac{a^2}{r^2}\right)\cos\theta\right\}\right]} \tag{17}$$

If, for example, $\alpha = 0.25$, we see from (14) that the value of σ given by (16) corresponds to a condition where the value of the potential-gradient with the sun at the zenith is 1.5 times the value with the sun at the antipodes.

Further, if, with this value of α, we choose β so that the conductivity at an altitude of 10 kilometers, with the sun at the zenith, is 30 times the corresponding value at the earth's surface,[1] we find $\beta = 1817$. Of course, (17) shows that the potential-gradient at this altitude would attain only about one thirtieth of its value at the earth's surface, as experiment shows to be the case. This latter conclusion, which is only a bi-product of the present problem, would of course have followed on much more elementary considerations than those here presented.

Writing

$$z = 1 - \left[\frac{a}{r} - \frac{\alpha}{3(1+\alpha)}\left(\frac{r}{a} - \frac{a^2}{r^2}\right)\cos\theta\right]$$

we see that

$$\frac{dz}{dr} = \frac{a}{r^2} + \frac{\alpha}{3(1+\alpha)}\left(\frac{1}{a} + \frac{2a^2}{r^3}\right)\cos\theta$$

so that z increases for all values of r for $\theta < \frac{\pi}{2}$, and even for $\theta = \pi$, z increases with r for values of r/a less than that given by

$$\left(\frac{a}{r}\right)^2 = \frac{\alpha}{3(1+\alpha)}\left[1 + \frac{2a^3}{r^3}\right]$$

For $\alpha = 0.25$ as cited above, the value of r/a greater than unity which satisfies this equation is approximately 3.82, giving $z = 0.99$ approximately. With the value 1817 for β, which was chosen above so as to make the conductivity at an altitude of 10 km. thirty times that at the surface, we should have, for the minimum value of σ at $r = 3.82a$,

$$\sigma = \sigma_0 \times 10^{781}$$

so that expression (16) indicates a practically perfect conductivity at $r = 3.82a$. Further, the expression indicates a more rapid increase of conductivity with altitude when $\theta =$ zero than for any other value of θ, and is thus of a type to represent qualitatively the influence of a radiation from the sun. The constant α may be taken as indicating the intensity of the sun's effect. Absence of any effect due to the sun would be symbolized by a zero value for α, in which case (16) would indicate equal rates of increase of σ and equal rates of decrease of $\frac{\partial V}{\partial r}$ for all values of θ. Moreover, (14) would, for this case, indicate constancy of the potential-gradient over the earth's surface.

It may be observed that the form which we have chosen for σ in this illustrative example, leads to a diminution with altitude when r is sufficiently great and $\cos\theta$ is negative. This fact is not fundamental to our problem, however; for if, in place of (16) for σ, any other function be chosen which is sensibly the same as (16) for $r < 3.82a$, then, for a given total charge on the earth's surface, the distribution of $\left(\frac{\partial V}{\partial r}\right)$ in the region $r < 3.82a$ will be sensibly equal to (17), as may be seen from the following argument, which is very similar to the usual proof of the uniqueness theorem for solutions of La Place's equation, and the equation of continuity.

[1] The results of A. Wigand (Terr. Mag., v. 19, pp. 93–101, 1914) indicate a value 37×10^{-4} E. S. U. for δ at 9,000 meters. For σ at the earth's surface, values ranging all the way from 0.4 to 3.0 E. S. U. are quoted.

Suppose there be two solutions V and V_1. Then, from Green's theorem,

$$\iiint (V-V_1)\left[\frac{\partial}{\partial x}\left(\sigma\frac{\partial(V-V_1)}{\partial x}\right)+\frac{\partial}{\partial y}\left(\sigma\frac{\partial(V-V_1)}{\partial y}\right)+\frac{\partial}{\partial z}\left(\sigma\frac{\partial(V-V_1)}{\delta z}\right)\right]dxdydz=-\iiint\sigma\left[\left\{\frac{\partial(V-V_1)}{\delta x}\right\}^2+\left\{\frac{\partial(V-V_1)}{\partial y}\right\}^2+\left\{\frac{\partial(V-V_1)}{\partial z}\right\}^2\right]dxdydz+\iint(V-V_1)\left[\sigma l\frac{\partial(V-V_1)}{\partial x}+\sigma m\frac{\partial(V-V_1)}{\partial y}+\sigma n\frac{\partial(V-V_1)}{\partial z}\right]ds \quad (18)$$

The left-hand side is zero on account of the equation of continuity. The surface integral is taken over the surface composed of $r=a$ and $r=3.82a$. Over $r=a$, V and V_1 are both constants. Over $r=3.82a$, V and V_1 are sensibly constant, in view of the enormous conductivity there. Hence, over each surface, the integral is proportional to the corresponding value of

$$\iint\left[\sigma l\frac{\partial(V-V_1)}{\partial x}+\sigma m\frac{\partial(V-V_1)}{\partial y}+\sigma n\frac{\partial(V-V_1)}{\partial z}\right]ds \quad (19)$$

This integral is zero: For, over $r=a$, σ is constant, and the integral is proportional to the difference between the total charges on the earth's surface for the two solutions, which difference is zero by the conditions of the problem. The integral (19) over the surface $r=a$ represents the difference of the total currents from the earth for the two solutions, so that this difference is zero; and, as a result, the difference between the total currents through $r=3.82a$, for the two solutions, must be zero. It follows from this last conclusion that the value of (19) over $r=3.82a$ is zero. Hence, the total surface integral in (18) is zero.

We thus conclude that the remaining triple integral in (18) is zero, and this necessitates that $V-V_1$ shall be, at most, a constant, since the triple integral is a sum of squares. Again, the constant must be zero, since $V=V_1$ over $r=a$. Hence, within $r=3.82a$, the two solutions V and V_1 are sensibly the same.

From the physical standpoint the significance of the above demonstration exists in the fact that the highly conducting layer acts as an electric shield, which prevents external agencies from doing more than produce a constant potential within. This, again, is of importance in showing us that the distribution of potential-gradient over the sphere $r=a$ has really resulted from the variable conductivity distribution assumed below the sphere $r=3.82a$, and is not a mere result of the conductivity distribution, and its concomitant charge distribution which our function (16) happens to predict for the extreme outer regions of the atmosphere ($r>3.82a$).

An interesting field of extension of the principles outlined in this article is to be found in the solar eclipse. We should expect that the sudden removal of the sun's rays from any part of the upper atmosphere would have the effect of decreasing the potential-gradient at the corresponding point on the earth's surface. This is in line with such experiments as have been made on the variation of the potential-gradient during the eclipse. Reverting to the crude illustration occurring at the beginning of this article, we may liken the removal of the sun's rays to the production of a dent on the inside of the outer conducting sphere figuring in the illustration.

RADIO DIRECTION CHANGES AND VARIATIONS OF AUDIBILITY.

By CARL KINSLEY and ALBERT SOBEY.

[Presented at the September meeting of the Institute of Radio Engineers, New York, N. Y., and published in their proceedings.]

SYNOPSIS.—The war afforded very good opportunity for experimenting with devices for discovering the source of wireless waves. This paper discusses experiments made with the radiogoniometer and with the audibility meter with a view to determining a possible relation between direction of source and audibility.

It is at once evident that variations of audibility and direction are in a large measure due to the changes in the uniformity of the transmitting medium. This is discussed to determine whether or not the observed discontinuities are explainable upon this basis. It is suggested that much is dependent upon the ionization of the atmosphere by sunlight and the consequent absorption of electrical energy, which would account for the greater radius of transmission at night; the existence of the reflecting Heaviside layer, at an altitude of about 80 km.; and the nighttime irregular character of the ionization at the base of the stratosphere, at about 10 km., forming variable reflecting surfaces for waves.—*C. L. M.*

INTRODUCTION.

The development of methods for the determination of the point from which radio signals originate was actively carried on during 1918. The radiogoniometer measurements played an increasingly important rôle during the fall of last year. It seemed probable that the so-called radio compass might be called on to an extraordinary extent to assist in the projected operations of the spring of 1919, when an extensive use of aircraft would make necessary an exact method of navigation for cloudy weather both by day and night.

There had been no opportunity, however, for an examination of the degree to which reliance could be placed upon that method of determining directions when the origin of the radio signals was known. During the winter and spring of 1919 we were fortunately able to carry on an extended series of measurements under the peculiarly favorable circumstances of widely separated stations operated by well-trained observers.

DISCUSSION OF PROBLEM.

It has been found that radio messages can be read at much greater distances than the previously existing theories of the transmission of electromagnetic waves had indicated as possible. As soon as an appreciable arc of the earth's surface had been spanned it became evident that the radio waves must bend around the earth. MacDonald [1] was one of the first to show that the waves might be refracted sufficiently. This theory criticised, corrected, and finally approved, has been discussed by Rayleigh and Poincaré,[2] also by Poincaré in a series of articles, [3] and by Love.[4] Other equations were developed by Nicholson in a series of papers,[5] and by Rybczynski.[6] Sommerfeldt [7] had introduced a correction term by considering a surface wave at the discontinuity in the specific inductive capacity which occurs at the earth's surface.

All of the comparatively simple theories differed materially in the assumptions made so that the constants differed widely. In one particular, however, they agreed,

[1] Proc. Royal Soc., vol. 71, p. 251, 1903. Proc. Royal Soc., vol. c. 72, p. 59, 1904. Trans. Royal Soc., vol. c. 210, A, p. 113, 1910.
[2] Proc. Royal Soc., vol. 72, A, 1903.
[3] La Lumière Électrique, vol. 42, 1908.
[4] Trans. Royal Soc., vol. 215 A, p. 105 and 125, 1915.
[5] Phil. Mag., vol. 19, 1910.
[6] Ann. der Physik, vol. 41, 1913.
[7] Ann. der Physik, vol. 28, 1909.

in that a damping factor depending on the cube root of the wave length appears. Attempts have been made to verify these equations by Austin [1] and by Fuller.[2] It was found that Austin and Fuller did not agree except that the damping factor contained the square root of the wave length. In that important particular they indicated the error of the equations previously obtained, in which the cube root of the wave length appeared. Further results are given by Hogan,[3] and by Trench,[4] who also failed to agree with previous work.

It should be noted that all of the measurements made were made only during daylight. Radio transmission is much more uniform during the daylight hours, although the waves are damped more rapidly. Marconi [5] first noted this variation, and gave evidence of great irregularity occurring at sunrise and sunset. Eccles [6] has discussed the matter at some length and Fleming has also collected the published information, and discussed the possible causes.[7]

The possibility of interference due to reflections of the electromagnetic waves, which might cause variations in signal strength or audibility, has received particular attention by Marchant [8] and by Eccles.[9]

The possibility of there being a conducting layer has been long recognized, possibly first by Fitzgerald. Dewar [10] also suggested that there might be a region permanently conducting by virtue of a large amount of free ionization. This was brought prominently to the fore by the discussion of Heaviside,[11] and the region is now known as the "Heaviside layer." It is generally assumed to be at an altitude of, about, 80 km. This lower limit is somewhat below the point at which the Aurora Polaris appears, which has now been fixed by Störmer.[12] and Vegard and Krogness [13] at possibly 85 km. with maxima at 100 km. and 106 km. It has been shown by Campbell [14] that the prominent green auroral line at .5770 μ is always present in the light from the sky. Undoubtedly, the effect of ultra-violet light in the sun's radiation very materially increases the ionization of the air and carries the ionization region due to this cause much below the layer of permanent ionization. It has been observed by Elihu Thompson [15] that violent auroral displays are accompanied by large induced potentials on telegraph lines, and at such times an unusually high state of electrification of the atmosphere exists. No exact determination of the effect of such electrical activity on radio transmission has yet been made. The cable companies report large earth currents during the time of auroral display.

The velocity of the electromagnetic wave has been measured, by a method having an accuracy in the time measurements within 1/100,000 second between the Eiffel Tower and Arlington, by Abraham, Dufour, and Ferrie.[16] It has been found that the time first obtained was 0.033 second and again 0.022 second. This difference was far above the experimental error and indicated a large change in the velocity of the electromagnetic wave. It is significant that the velocity was considerably below that of light. One of the authors reported that the most probable value could be explained on the assumption that, the path of the wave was at a height above the earth of 50 km. This suggests that the Heaviside layer at 80 km. plays an important rôle.

It is therefore probable that the electromagnetic waves can be transmitted around the earth between the Heaviside layer and the earth as between two conducting surfaces. This would be particularly true at night, while during the daytime the intervening space would have large ionization well distributed. It has been pointed out by Eccles [1] that although the conducting surface of the Heaviside layer has been lost by the added ionization due to the sunlight, still the waves can be transmitted around the earth by the refraction thereby resulting. This possibility is argued at length since previous theories had not taken this view of the effect of the distributed ionization. The influence of water vapor has generally been neglected, but Schwers [2] shows that it might alone account for the refraction of the wave around the earth. He states, however, that probably the ionization of the air is of more importance.

The transmission of radio signals can occur over extraordinary distances, such as the reception in Australia of messages from Carnarvan, England, a distance of approximately 19,000 km. (12,000 miles) when the receiving station used a low antenna and a one-stage amplifier. This result was repeatedly obtained for several months, during the winter of 1917. Other cases where even more astonishing results, of 8,000 km., when only a 2 kw. transmitter is used, have been frequently reported. Such results are usually classed as freak performances, but they are none the less real and must be provided for in any general theory of radio transmission.

The foregoing facts, well known to radio engineers, are given with great brevity and the proposed theories have been pointed out. It must be evident that an adequate theory of the transmission of radio signals must explain all of the established facts, such as—

(1) The difference between daylight and night transmission.

(2) Irregularities occurring at sunrise and sunset.

(3) Special irregularities such as might be caused by interference.

(4) The phenomena of direction changes in the electromagnetic wave, with the experimental determination of which, the body of this paper is concerned.

The direction changes play an important part in the phenomena of the transmission of electromagnetic waves, which has been found to be so complex. It is also of great practical importance to determine to what extent the direction of radio signals as measured by the radio goniometer can be depended on, since the proposed radio 'lighthouses" might be a source of danger instead of safety. Changes of audibility have also been obtained so as to determine whether or not there is any relation between the two.

The causes for the departure from the normal direction of the transmission of radio signals as well as their varying audibility can be expected to be explainable on a basis of changes in the uniformity of the transmitting medium. This will be considered at some length for the purpose of determining whether or not the physical conditions existing afford the necessary discontinuities to explain the variations observed.

[1] Bul. Bureau of Stand., vol. 7, p. 315, 1911. Bul. Bureau of Stand., vol. 2, No. 1, p. 81, 1914. Proc. Inst. Radio Eng., vol. 3, June, 1915. Jour. Franklin Inst., November, 1916.
[2] Proc. Am. Inst. Elect. Eng., April, 1915.
[3] Electrician, vol. 71, p. 720, 1913.
[4] Electrician, vol. 79, pp. 102, 147, and 181, 1917.
[5] Proc. Roy. Soc., June, 1902; Proc. Roy. Inst., 1911.
[6] Proc. Roy. Soc., vol. 87, A, p. 79, 1912.
[7] Wireless Telegraphy, p. 843. Electrician, vol. 74, p. 152.
[8] Proc. Inst. Radio Eng., p. 512, 1916.
[9] Proc. Roy. Inst., vol. 87, 1912.
[10] Proc. Roy. Inst., vol. 17, p. 223, 1902.
[11] Electrical Papers, vol. 2, p. 152.
[12] Terr. Magnet and Atmos. Elect., vol. 21, p. 157, 1916.
[13] Terr. Magnet and Atmos. Elect., vol. 21, p. 169, 1916.
[14] Astrophr. Jour. 2, 162, 1895.
[15] Proc. Nat. Acad. of Sci., vol. 3, January, 1917.
[16] Compt. Rend., vol. 159, p. 38, July 6, 1914.

[1] Proc. Roy. Soc., vol. 87, A., p. 79, 1912. Electrician, p. 1015, Sept. 27, 1912.
[2] Proc. Phys. Soc. of London, vol. 29, pt. 2, Feb. 15, 1917.

METHODS AND RESULTS OF RADIO TESTS.[1]

For the measurement of the direction of propagation of the wave received at any station (see fig. 1), a loop was employed which could be freely rotated about a vertical axis. If the wave-front is vertical, the loop, rotated about a vertical axis, will have a maximum potential difference across its terminals when its plane is at right angles to the wave front. This results in a maximum strength of signal. When the plane of the

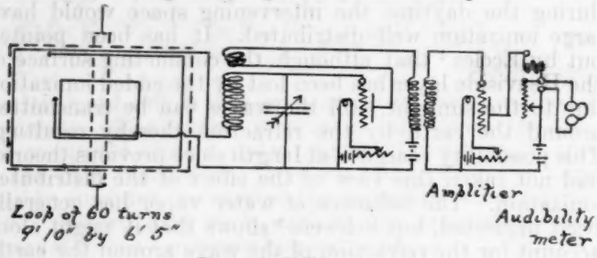

FIG. 1.—Audibility meter.

loop is parallel to the wave front, there is no current set up in the oscillating circuit, composed of the loop and the tuning condenser, which results in complete silence in the receiving telephone. If the loop is rotated about a horizontal axis, there is no change in the audibility of the signals in the receiving telephone.

The loop used at Houlton, Me., for these measurements is as follows: Sixty turns, No. 26, B. & S. solid copper wire, D. C. C. wound in one plane with horizontal wires spaced 0.4 inch and vertical wires 0.6 inch apart. The outside dimensions of the loop are, therefore, vertically 6 feet 5 inches, and horizontally 9 feet 10 inches. The loop was 7½ inches below the ceiling and 9 inches above the floor, having a clearance of 6 inches at one point from the wall and 12 inches at the other, in a room on the lower floor of a small detached wooden house. The vertical axis about which the loop was turned was pivoted to floor and ceiling.

Figure 2 gives a polar curve of audibility changes as the receiving loop is rotated. This curve is thoroughly

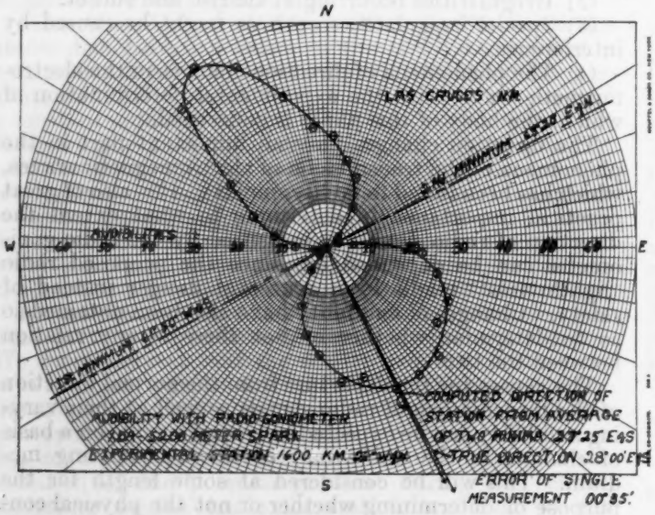
N
E
S
W
AUDIBILITY WITH RADIO GONIOMETER
LOOP 6200 METER SPARK
EXPERIMENTAL STATION 1600 KM. 62° W of N
COMPUTED DIRECTION OF STATION FROM AVERAGE OF TWO MINIMA 37°25' E of S
TRUE DIRECTION 28°00' E of S
ERROR OF SINGLE MEASUREMENT 00°85'

FIG. 2.—Polar curve of audibility.

characteristic. The difference in its upper and lower part is due to the design of the loop which was purposely constructed so as to indicate the absolute direction of the radio signals. It has been found from many tests that the minima lie 90° from the direction of transmitting station, using normal daylight conditions. It is to be noted that this is true even though the maximum

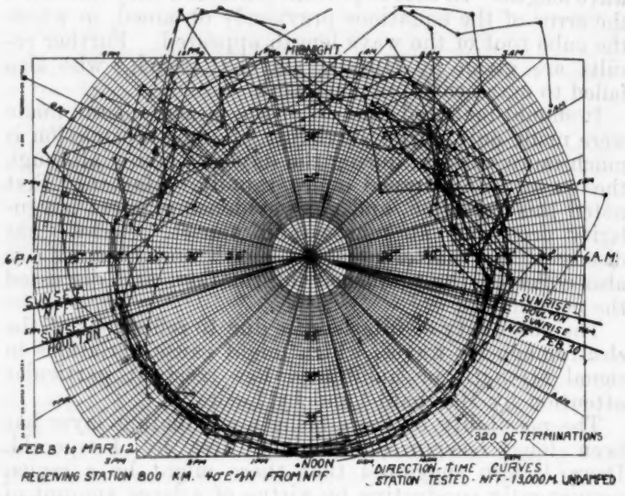

FIG. 3.

vector does not lie along this direction. In the figure shown a difference of about 10° will be noted while the direction of the transmitting station as computed from the minimum values is in error by only 35′.

Figure 3 gives a series of direction determinations made as described above and each direction is the result of a computation from the accurate determination of the minima of a polar curve, each of which required nine audibility readings. It will be noted that during the sunlight hours the direction measurements varied but little and the values could be used for determining the location of the transmitting station. During the night, however, the direction measurements showed extremely erratic values.

Figure 4 is drawn from a continuous series of observations made during one week. The same methods were employed as just described.

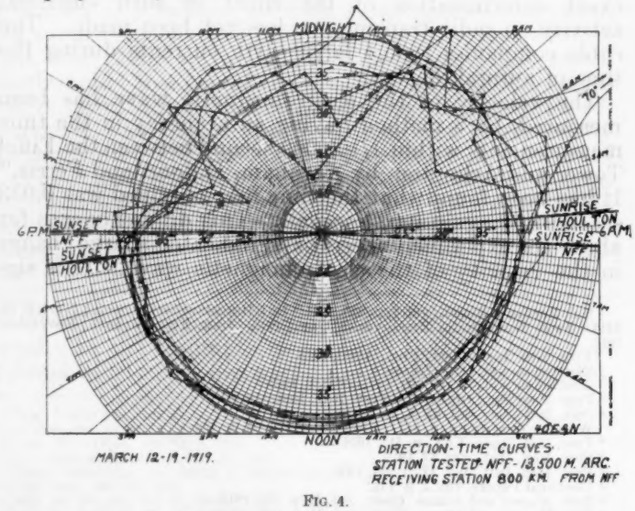

FIG. 4.

It is particularly noted that all of the cases observed when no directional measurements could be made ap-

[1] Abstracted from the original.—C. L. M.

peared during the night, and also, in the large majority of them, bad weather conditions prevailed.

Figure 5 gives all of the directions obtained during the particular seven hours when occurred the widest variation noted during the week's test shown in figure 4. In a figure there are plotted in two instances the data employed in computing one of the two minima, the average of which gives a single point on the curve of this figure, taken March 19. There was no rain at Houlton, but there was rain in every other town in Maine on Weather Bureau list.

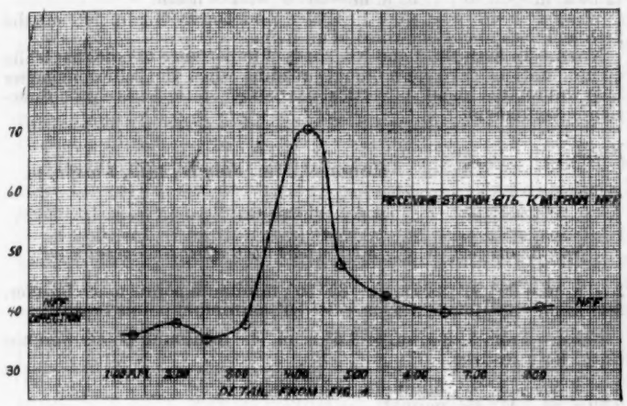

FIG. 5.—Detail from fig. 4.

Figure 6 illustrates the phenomenon often observed and known as "swinging" of the audibility. The audibility measurements were made by the shunted telephone method and thus varied by steps of considerable magnitude. That is the cause of many of the observations showing exactly the same audibility, while a more accurrate method would have distributed the values.

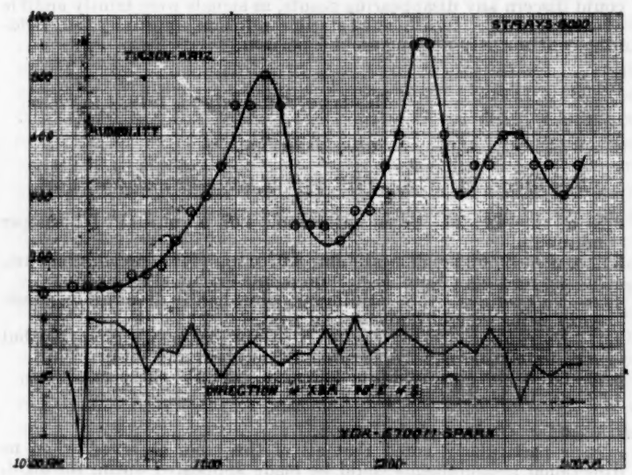

FIG. 6.—"Swinging" of audibility.

These observations were taken June 16–17 at Tucson, Ariz. The sky was clear but the strays were reported as heavy.

During the time covered by these observations, there was but little change in the direction measurements, and the only rapid change in direction noted, occurred during the time that the audibility of the signal was constant.

It should be stated that the audibility measurements were made not with the use of the loop, but instead by using a vertical antenna which was located at more than 0.2 km. from the loop station. It was proved by experiments, that no interference existed between the two receiving stations, one independently employed in making audibility measurements, and the other in determining by the loop the direction of the radio transmission.

In the following figure the same methods outlined above for determining audibility of the signals and the directional measurements were employed.

Figure 7 primarily intended to show that the same station may exhibit widely fluctuation values of audibility with negligible changes in direction, and also the converse of large and rapid changes in direction with inconsiderable changes in audibility.

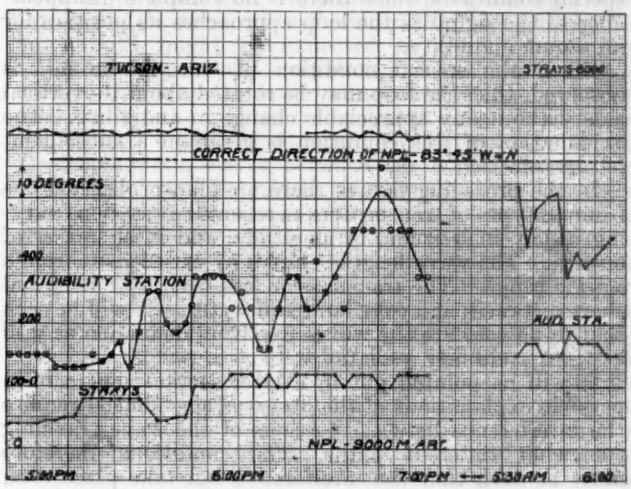

FIG. 7.

There are shown also in this figure values for strays which in the first case were comparatively low, and in the second were extraordinarily high. It is believed however that the presence of high strays is no indication of excessive changes in audibility.

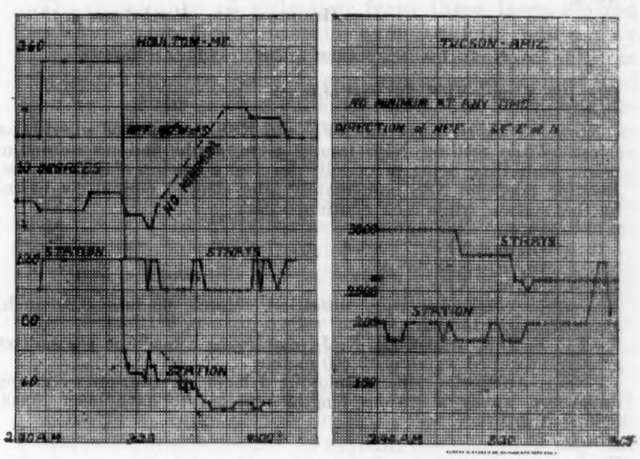

FIG. 8.—Showing complete loss of directional effect.

Figure 8 illustrates a very special case where the radiogoniometer loop exhibited no directional effect when rotated about a vertical axis. At the same time the same transmitting station was observed at both Tucson, Ariz., and Houlton, Me., and throughout the whole period at Tucson no direction could be obtained. The weather condition at Houlton, Me., was overcast

sky but no rain, while at Tucson, Ariz., there were bad static conditions, with lightning around the horizon but with no precipitation of rain during the day, July 11.

The observation at Houlton, Me., showed uniform direction measurements somewhat displaced from normal, and with a broadening of the minimum. This means that the changes of audibility in the neighborhood of the minimum position of the loop, as the loop is rotating, was less rapid than normal and also with a maximum audibility of the usual value it would be found that the signals did not completely disappear when the loop was in the condition showing the minimum audibility. Frequently it is necessary to determine the position of the loop for minimum, by a single observation under these special conditions, since there is no complete disappearance of the signal as the loop approaches its position for minimum audibility.

When the special condition of "no minimum" is observed, then the loop may be rotated about its vertical axis without any appreciable change in audibility. The explanation of this condition is given in a subsequent paragraph.

In the preceding figures there are shown observations from all types of transmitters as received at stations varying widely in latitude, in longitude, and in character of terrain. The wave lengths employed varied also through a wide range. The transmission has been over long and short distances and over land and water. It will be seen that in no case are the waves free from distortion as well as from audibility variations.

It will be pointed out in a later section that certain possible explanations of the observed phenomena require the interference between portions of the wave traveling somewhat different paths. The conditions therefore must be such that the interference can take place even when the wave length is short and the wave train is the damped one given by a spark system.

TABLES.

NO MINIMUM AUDIBILITY AS RADIOGONIOMETER LOOP WAS ROTATED ABOUT A VERTICAL AXIS.

No. 1.

HOULTON, ME., *March 6 and 7, 1919.*

1 A. M. TO 7 A. M., MARCH 7, 1919. SERGT. HEINLINE.

1.15–1.28 a. m.—NFF. 36° east of south.
2.00–2.10.

NOTE.—Took readings on NFF and NSS and plotted curves for same. While reading NFF from 2 a. m. could find no minimum point, audibility being practically level at all points of the compass. Reading taken on NSS immediately after showed normal conditions for that station, while NFF continued flat.

2.10–2.24 a. m.—NSS 42° 30′.
3.12–3.25 a. m.—NFF 27° 00′.
3.27–3.36 a. m.—NSS 43° 45′.
4.45–4.55 a. m.—NFF 41° 45′.

Weather conditions were unsettled. March 6, rain 0.20 inch; March 7, rain 0.10 inch.

NFF is New Brunswick, N. J., employing a machine transmitter giving undamped waves of 13,500 meters.

NSS is Annapolis, Md., employing a large arc transmitter giving undamped waves of various lengths reported to have been 15,000 meters at this time.

No. 2.

HOULTON, ME., *6 p. m., April 24, to 1 a. m., April 25, 1919.*

SERGTS. PFEIFFER AND M'ALLISTER.

Glace Bay, GB, with 8,000-meter spark.

10.24 p. m.—12° 30′; 11.02 p. m.—12° 30′.
10.43 p. m.—12° 30′; 11.20 p. m.—12° 30′.

Arlington, NAA, with 2,500-meter spark.

11.30 p. m.

NOTE.—NAA was tuned in on both of the loop receiving sets, but in neither case was it found possible to get definite disappearing points.

Mexico City, XDA, with 5,700-meter spark.

11.38 p. m.—27° 30′ west of north; 11.59 p. m.—25° 0′.
11.49 p. m.—27° 30′ west of north; 12.01 a. m.—42° 30′.
11.50 p. m.—29° 0′ west of north; 12.25, no minimum.

NOTE.—Disappearing points began to spread and in next minute no minimum points could be distinguished. This condition continued until 12.32 a. m., when it quickly changed and the following readings were taken:

12.34 a. m.—26° 0′; 12.52 a. m.—26° 0′ west of north.

Weather conditions were unsettled and traces of rain fell on the 24th and 25th about one-third of an inch.

NOTE.—In both No. 1 and No. 2 it is of importance to note that while certain stations gave *no minimum* reading when the radiogoniometer loop was rotated about its vertical axis, other stations gave good direction measurements.

No. 3.

HOULTON, ME., *July 11, 1919, 1 to 8 a. m.*

M.S.E. PFEIFFER.

New Brunswick, N. S., NFF with 13,500 meter undamped wave.

3.50 a. m.—35° 30′; 3.24 a. m.—32° 30′; minimum points much broader.
3.17 a. m.—33° 45′; 3.27 a. m.—34° 30′, minimum points broad.

NOTE.—From 3.33 a. m. to 3.58 a. m. the minimum points were too broad for a reading.

3.50 a. m.—42° 30′, minimum points sharp.
3.59 a. m.—41° 45′, normal.

Weather: Overcast, light south breeze, cool; no rain.

No. 4.

TUCSON, ARIZ., *July 11, 1919, 8 a. m. to 4 p. m.*

CORP. WM. F. AUFENANGER.

New Brunswick, N. S., NFF, with 13,500 meter undamped wave.

NOTE.—NFF heard from about 3 a. m. to end of watch, but was very weak. During transmitting periods neither Capt. Ives nor operator could discern any disappearing points, as signals were faintly audible over entire 360°. Weather and static conditions unusually bad, lightning continuously playing around horizon.

No. 5.

HOULTON, ME., *July 13, 1919, 1 to 8 a. m.*

M.S.E. PFEIFFER.

New Brunswick, N. S., NFF, with 13,500 meter undamped wave.

3.20 a. m.—43° 30′, broad minimum; 4.02 a. m.—41° 0′, sharper minimum.
3.57 a. m.—42° 0′, broad minimum; 4.07 a. m.—44° 0′ broad minimum.
4.29—No reading. Note: Minimum points too broad for reading.
4.39—No reading. Note: Minimum points hardly discernible, apparently being around due east and west.
4.47—No reading. Note: Minimum points continually changing, but very indefinite, now being around due north and south.
4.49—55° 0′, broad minimum; 4.57 a. m., 44° 30′, sharp minimum.
4.52—48° 0′, slightly sharper.

Weather: Clear, cool, full moon.

It is particularly noted that all of the cases observed when no directional measurements could be made apppeared during the night, and also in the large majority of them bad weather conditions prevailed.

DISCUSSION OF RESULTS.

It has been shown that radio telegraphic signals of all kinds, including transmitters employing high-frequency alternators and arcs, giving undamped waves of 4,900 to 17,300 meters length, and various spark systems having damped waves from 960 to 5,700 meters wave length, suffer distortions whether transmission is over land or

over water. Many observations have been taken which are not shown in the figures, covering a distance range from 65 km. (Annapolis, 17,300 meter arc received at Washington) to 12,000 km. (Funabashi, 3,800 meter spark, received at McAllen, Tex.). In all cases, neither the character of the transmitter, the wave length employed nor the local conditions of terrain have been effective in preventing the distortion of the electromagnetic wave used in signaling.

The changes in audibility have also been obtained by an extended series of experiments, but the figures presented show only a few particular cases where it is desired to bring out the fact that large changes in direction are not necessarily accompanied by any considerable changes in audibility of the signals and that even an entire loss of directional effect by the receiving loop may occur with no considerable change of any character in the audibility of the signals.

The converse may also be true and it is shown that there may be very large changes in the audibility of the signals without any appreciable change in the direction.

In general, it can be said that the changes in audibility are of much more frequent occurrence and are proportionately much larger than the changes in direction. It seems, also that the audibility changes follow a diurnal cycle as well as a seasonal cycle. Probably the underlying causes for the two changes are the same, but the directional changes only occur when the underlying causes produce a very special condition which does not have any considerable effect upon the energy absorption.

It might be expected, therefore, that most audibility variations would be produced by changes in the energy absorbed by the transmitting medium and more rarely by interference phenomena when the ionization causing absorption in general is so concentrated and segregated as to produce sharply defined conducting strata; this would act as a reflector for the electromagnetic waves under conditions where the difference in path between a direct and reflected wave would be at most only a few half-wave lengths, and the angle would be small between the reflected and direct wave. The change in directional effect might be produced by the combination at the receiver of a direct and a reflected wave, but it would be necessary for the reflection to take place from a surface sufficiently removed in a horizontal direction from the receiver that the reflected wave would have a very considerable horizontal component in order to cause the loop turning about a vertical axis to give an indication of a directional change.

In the second class of directional changes it is assumed that there are two components which have a quadrature relation both with respect to time and direction. This would require a reflected wave, as indicated above, from a surface at a considerable distance in a horizontal direction from the receiver and at a distance which would make the reflected electromagnetic wave 90° out of phase with the direct wave. If the distance were such that this phase difference was not 90° then the resultant wave at the receiver would show a direction depending upon the composition of the direct and reflected wave with respect to amplitude and direction. The phase combination of this reflected and direct wave might be almost anything, but would not affect the audibility of the signals as received by the loop, and so would not affect the general measurements upon which the direction indications depend.

We need now to examine with care the complex state existing in the atmosphere through which the electromagnetic waves travel in order to determine the physical conditions upon which depend the observed phenomena of the direction changes and variations of audibility and strays.

The latest information that we have in regard to the condition of the atmosphere shows that there are certain regions where there are discontinuities such as to make possible the formation of reflecting surfaces, assumed in our explanation of the observed phenomena. There are—

First. The Heaviside layer, assumed to be about 80 km. above the surface of the earth, which has been discussed at considerable length by previous investigators.

There seems to be no doubt but that there would be a discontinuity and that it might very well happen that it would be much more pronounced during the night than during the daytime, when the ionization produced by the sun's light might be expected to extend below the stratum of permanent ionization, diminishing rapidly as we proceed into the lower atmosphere. It might very well be that the greater transmitting distances observed during the night are obtained by the passage of the electromagnetic waves between the conducting surface of the earth and the conducting region of the Heaviside layer, which being a region of permanent ionization has a lower surface showing a sharp discontinuity, as soon as the ionization stops upon the disappearance of the sun and the ions present have rapidly recombined. There would then, within this region below the Heaviside layer, be comparatively little free ionization and consequently but little absorption, allowing thus the transmission of radio signals over excessively long distances. During the daytime the widely distributed ionization caused by the sunlight would result in large absorption of the energy, and this condition would be generally found to exist at all points. Irregularities in recombination at the disappearance of the sunlight might very well produce large regions in which the uniformity of the conducting layer is broken and where there persists for a time absorbing regions which would have considerable effect upon the audibility of the signals and an erratic effect, as is usually observed in the case of the reception at night of radio signals.

The possibility of reflection from these large ionized masses or from the Heaviside layer itself in such a way as to produce the interference phenomenon, which has long been known to the radio engineer as a "swinging" and "fading" of the radio signals at night, has been examined in detail by a number of engineers, and their conclusion will be found in the literature on the subject. It does not seem to us that it would be possible to have an interference produced by these reflections at the receiver, since the number of half-wave lengths difference between the two paths necessary in order to account for the observed phenomena would be so great as to make any sharply defined interference pattern out of the question, considering the nature of the reflecting surfaces and the characteristics of the transmitting medium. This would also be even more evident in the case of the changes of direction, since the distance would be very considerably greater on account of the necessity for having the horizontal component needed to explain the observed angular displacement of the direction of the wave.

Second. The diurnal vertical convection is limited to from 500 to 1,000 meters above the surface of the earth, depending upon the season of the year and the condition of the weather.

There would be a discontinuity which would appear at about the place where the measurements of penetrating radiation have shown that the effect of the radioactive

constituents of the earth disappears. It does not seem to us that this would be a sufficiently well-defined discontinuity to account for the reflecting strata needed to account for the observed phenomena.

Third. There is, during the summer, a region which is defined by the cumulus clouds at 4 or 5 km. above the earth. We do not believe that this discontinuity is sufficient to account for the results.

Fourth. There is, at an elevation of approximately 7 km., a region known as the alto-stratus layer, which is present in both summer and winter. This layer is not sufficiently well defined, and the causes for the discontinuity are not such as to lead us to believe that the observed phenomena can be accounted for by any reflections at this altitude.

Fifth. There is always found a sharp dividing line between the troposphere and the stratosphere (isothermal layer) which occurs at an average altitude of 10 km. This is dependent somewhat upon the season and also the storm areas. It is found that changes as large as 3 km. may exist between the cyclonic and anticyclonic regions. At this sharply marked boundary there is undoubtedly a layer of cosmic dust which may very well be strongly radioactive. This is also the region where the cirrus clouds usually form, and which is consistently their upper limit. It is the most sharply marked discontinuity of which we have any definite knowledge in the upper atmosphere.

It is probable that such a stratum is present during the night when there is little movement in the upper part of the troposphere and that this conducting layer forming the boundary between the troposphere and stratosphere, will act as an excellent reflector. The movement caused by a cyclonic disturbance will change, however, the inclination of this conducting layer. There may also be considerable regions in the part of the troposphere bordering on its discontinuity which are strongly ionized, due to the upward drift of the negatively charged particles and water vapor which have been segregated in sufficiently large quantity so as not to be immediately neutralized after the disappearance of sunlight. The cessation of the turmoil resulting from the convection currents caused by the sun's action will allow these ionized regions to assume a stratified form which will act as excellent reflecting surfaces.

A soon as the sun reappears and covection currents are reestablished, they both destroy the sharply defined conducting layer and cause a widely distributed ionization which absorbs much of the available energy. The result is a decrease in signal strength, but no considerable distortion in the direction of the transmission.

During the night the long-distance transmission could take place between the earth and the Heaviside layer with the intermediate conducting stratum at approximately 10 km. above the earth's surface, playing but little part until some discontinuity caused it to act as a reflector. This conducting layer would also make possible abrupt local changes in energy due to absorption which would later be equalized by a gradual distribution through the conducting layer, which is, of course, not perfect, from the region lying between it and the Heaviside layer.

During the daytime the greater ionization and its wide distribution below the Heaviside layer, as well as the constant occurrence of ionization below the stratosphere, would both tend to absorb the energy of the electromagnetic wave, and so decrease the observed signal strength at the receiving station, while preventing the reflections necessary for the distortions observed during the night.

In the same way also the periodic change in audibility or "swinging" may be due to the movement of interposed conducting masses of air which absorb the energy of the wave. This would be particularly true when the periodic change occurs through a considerable time. The interposition of a series of storm regions moving along the same direction would produce such changes in audibility. A test of this might be the determination of such variations with respect to a north and south line and an east and west line, since there is a decidedly greater storm movement along the east and west line.

There is consequently the condition necessary for reflection from the stratum which is approximately 10 km. above the surface of the earth. The distance is such that it will permit the formation of interference patterns at the receiving station, since the number of half waves would not be too large to make that possible. This might occur quite rapidly and be due to the interference of a direct and reflected wave when the reflecting surface is changing its position with a velocity often found in the movement of cloud masses. The entire disappearance of directional effect when due to the rotation of the electromagnetic field would also be easily possible when the reflection occurs from the ionized layer between the troposphere and stratosphere or from an ionized stratum below that boundary.

It would be expected that the changes in direction would occur therefore, only when the discontinuity due to the stratification of the ionized gases and particles became effective during the night hours, and that these changes in direction would be produced only by reflection and never to any appreciable extent by a refraction, so that changes of small amount might be expected to be of frequent occurrence, while changes of large amount requiring a reflection from a surface beyond the receiving station, so as to allow the resultant direction caused by the combination of the reflected and direct waves to make a shift as great as the change of 56° 30′ in 13 minutes, as shown, would be of much more infrequent occurrence than the audibility changes continually observed. Also the very special case where there is a complete disappearance of directional effect would not be produced except under very special circumstances which might not be expected to occur except at rather infrequent intervals.

The results obtained have been quite disconcerting to those of us interested in making a quantitative use of the directional characteristics of the loop, but it is believed that a knowledge of what may occur, although rarely, will be of material assistance in further work. It is possible also that our knowledge of the upper atmosphere may be greatly advanced by a systematic employment of high frequency oscillations and the use of quantitative methods in radio measurements.

STRATOSPHERE TEMPERATURES.

[Discussion.]

In the March, 1919, number of the MONTHLY WEATHER REVIEW, Prof. Humphreys offers a tenable explanation of the comparatively low temperature of the base of the stratosphere. There remains the matter of the higher temperature of the greater heights of the stratosphere. Here are two feasible explanations, but neither is supported by positive evidence.

The first is the question of dust. If no dust, either cosmic or telluric, exists within the air of the stratosphere, then it differs from the air of the lower shell and leaves to be explained how cosmic dust can reach the earth. Dust is matter and if solar radiation sets up molecular motion in other matter it can not skip the dust particles; and since they can not absorb heat indefinitely they must become sources of radiation. Small as the dust particles of the stratosphere may be, it is immeasurably more than the molecule and its radiant power is great in proportion. Moreover, the curvature of surface, which affects the heating of high latitudes of the earth, does not affect the heating of dust particles at a distance from the earth. The cosmic dust of polar regions is not hidden in shadows; it is in perpetual sunlight.

There is also the possibility of heat from radio-activity in the stratosphere and of this form of energy there can be little doubt. Whether its source is highly electrified dust particles or some other form of matter does not concern the question. Some of it at least is transformed into heat. The only question is, does the transformed energy add appreciably to the temperature of the stratosphere?—*J. W. Redway, Meteorological Laboratory, Mount Vernon, N. Y.*

The temperature changes with elevation in the stratosphere appear to vary considerably from day to day. Thus:

1. The minimum temperature occurs at the base of the stratosphere; especially over an anticyclone. This appears to be the result of forced convections—the overrunning of northerly by westerly winds.

2. The recorded increase in temperature with elevation above the base of the stratosphere doubtless does not always represent the actual temperature distribution of the upper atmosphere. At these levels ventilation of the thermometer is occasionally insufficient, and the recorded temperatures therefore too high; unless obtained at night, which they seldom are.

However, there necessarily is some gain of temperature from the forced minimum at the base of the stratosphere to the somewhat higher temperature of radiation equilibrium—the temperature at which emission and absorption of radiation are equal. Now, the temperature at which emission is equal to the absorption, when the intensity of the incident radiation is constant, varies with the composition, or nature of the material concerned. Hence, as the composition of the atmosphere certainly must change with elevation it follows that there must also be some changes in the equilibrium temperature. Whether the equilibrium temperature of cosmic or other dust in the stratosphere is higher, or lower, than that of the air of that region is uncertain. It is certain, however, that the probable amount of such dust is too small for it to affect appreciably the temperature of the stratosphere in any case.

3. The temperature changes of the stratosphere as between cyclonic and anticyclonic regions probably are chiefly of dynamical origin, modified, perhaps, by changes in the intensity of the radiation from the lower atmosphere.

4. The thermally streaky, or stratified, condition of the upper atmosphere can only be due to imperfect mixing. Over anticyclones the stratosphere is, on the average, several degrees colder than it is over cyclones. Again, above a wide layer of cirrus clouds the upper air necessarily receives less incident radiation because cut off from below, and therefore grows colder, than it does when the skies are clear. In short, the stratosphere is unequally heated over different regions; and consequently its incessant horizontal circulations always keep it more or less thermally stratified.—*W. J. Humphreys.*

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BENJAMIN FRANKLIN'S RISK WITH LIGHTNING.

[*Reprinted from* Scientific American, New York, Aug. 9, 1919, p. 128.]

SCRANTON, PA., July 27.—When emulating Benjamin Franklin late yesterday afternoon, Andrew Loyak, of this city, was killed when a bolt of lightning followed the wet kite string from the skies. Loyak was struck in the back of the head. Death was instantaneous.

The above news item in the New York Times of Monday, July 28, 1919, affords material for laying proper emphasis on the great danger attending modern kite flying whether during thunderstorms or at less obviously dangerous seasons. Our natural desire to emulate the great scientist and statesman referred to, must be tempered by the more modern knowledge that Franklin's classic experiment was a very foolhardy one—though he did not know it.[1] * * * Our meteorological kite flyers use large-sized box kites held by fine piano wire and therefore would run the greatest danger from shocks and lightning strokes. They know this, have repeatedly seen the thin steel wire go up in a streak of rusty smoke, and therefore are very careful never to neglect making a very good "ground" from the reel or wire carrier to the wet soil where they must be to work the kites. The fliers themselves keep as dry as possible and avoid contact with the wire or string. Instruments devised for measuring the potential on the kite wire frequently indicate high voltages and a little spark gap in the circuit would show an almost constant flow of current from the kite and the wire through the reel into the ground. * * *

Considerable shocks have been experienced by the curiously inclined on perfectly clear days. * * *

If you use a reel for the kite string be sure to ground it as carefully as you would *any other lightning rod*, stand on dry ground yourself, and leave the string alone.

[1] Out of justice to Franklin, Prof. A. McAdie (in *Sci. Am.*, Sept. 6, 1919, p. 229) makes the following remarks:

"One sometimes sees on a bank note a picture of Franklin defying the lightning. There is the philosopher standing *out of doors*, with the approaching cloud and lightning flashes such as never occur in fact. It is explicitly stated in the letter [to Collinson, Oct. 19, 1752, old style] that the person holding the string 'must stand within a door or window or under some cover so that the silk ribbon will not be wet.'"

MOUNTAIN AND VALLEY WINDS AT SYRACUSE, N. Y.

By ERNEST S. CLOWES, Assistant Observer.

[Dated Aug. 19, 1919, Syracuse, N. Y.]

While mountain and valley winds are usually associated with the relatively narrow valleys leading up to high mountain ranges there have been a few cases recorded of these typical winds where the topographical features were not so strongly pronounced. Such cases have been noted at Utica, N. Y.[1] and at Ithaca, N. Y.[1] and a further interesting example may be found at Syracuse in the same State.

Before considering the local topography at Syracuse it might be well to give a brief glance at that of central New York in general. This section is very sharply divided into two parts, the interior plateau, and the northern plain which extends for 30 to 40 miles south and southeast of Lake Ontario. The line of division is a little south of and parallel to the old Erie Canal which runs through the center of Syracuse. The canal has here an elevation above sea level of about 400 feet and the land to the north of it is generally level and of about the same altitude. Southward it rises quite abruptly 150 to 200 feet and continues to rise rather steadily until elevations of 2,000 feet above sea level are reached about 20 miles south. The topography is so pronounced that viewed from the north side of Oneida Lake, 20 miles northward across the plain, the highlands extend in a wall from southeast to southwest quite like a distant range of mountains. The edge of this plateau passes through Syracuse. The greater part of the city lies on the plain but has spread up on the hills, which bound it on the east, south, and west, and which within a couple of miles rise about 200 feet above the center of the city. On one of these hills to the southeast the Weather Bureau station is located; the wind vane being 113 feet above the surface of the ground and about 300 feet above the level of the plain. To the southeasterly the land rises in irregular hills, the general trend being upward for about 25 miles. South and southwestward and directly south of the city is the valley of Onandaga Creek. This valley is about 2 miles wide at the entrance and extends inland about 8 miles. Such are the topographical features in the neighborhood of the station.

The accompanying table shows the prevailing hourly direction of the wind for every hour of the day, by months, and has been compiled from records of 16 years. The diurnal variation from south to northwest is clearly marked for every month except for November to February, inclusive, and the hour of the shift in the wind is quite clearly indicated. In conformity with most observations of such winds the wind from the hills is shown to be more pronounced during the winter when its force in this case is sufficient to mask entirely the northwesterly wind that prevails at that season in this latitude and pull it around into a westerly or southwesterly direction. This is readily explained by the greater radiation from the hills during the long winter nights. Neighboring stations in the hills at elevations of even 1,300 feet above the sea show January normals a degree or more below Syracuse and the difference must be more pronounced at higher levels especially at night. There is a singular exception to the general plan of the wind system during February, which although a cold month, has less south wind than any month in the year. This may be due to the fact that the northwest wind at that time is strong enough to prevail over the local circulation to the extent of pulling the night wind from the south around as far west as shown in the table.

It would be interesting to determine whether this diurnal wind system extends uniformly along the whole northern slope of the plateau region of central New York or whether it is confined to localities, such as Syracuse, that stand at or near the lower end of valleys. A fact that points to the former conclusion is that although the Weather Bureau station at Syracuse is well up on the eastern slope of the valley the night wind seldom shows an easterly component and southeasterly winds are comparatively rare. It may be added in conclusion that when a south wind is normally to be expected here, because of general cyclonic conditions, it is usually stronger than the pressure gradient would indicate, especially at night; and the highest velocities recorded here at all seasons except from summer thunderstorm squalls have been from the south, which direction also holds the record for the absolute maximum velocity.

[1] E. T. Turner, "The climate of the State of New York." Fifth Ann. Rept. Met. Bureau and Weather Service of the State of New York.

Prevailing hourly wind directions for every month in the year at Syracuse, N. Y.

[Based upon records of 16 years.]

Hour.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Means.
1 a. m.	S.	W.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.
2 a. m.	S.	W.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.
3 a. m.	S.	W.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.
4 a. m.	S.	W.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.
5 a. m.	S.	W.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.
6 a. m.	S.	W.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.
7 a. m.	S.	W.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.
8 a. m.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.	S.
9 a. m.	S.	S.	nw.	nw.	W.	W.	S.	S.	S.	S.	S.	S.	S.
10 a. m.	S.	S.	nw.	nw.	nw.	nw.	S.	S.	S.	S.	S.	S.	S.
11 a. m.	S.	S.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	S.	S.	sw.	nw.
12 noon	S.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	S.	sw.	nw.
1 p. m.	S.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	W.	sw.	nw.
2 p. m.	W.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	W.	W.	nw.
3 p. m.	W.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	W.	W.	nw.
4 p. m.	W.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	W.	W.	nw.
5 p. m.	W.	W.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	W.	W.	nw.
6 p. m.	W.	W.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	W.	sw.	nw.
7 p. m.	W.	W.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	S.	W.	sw.	nw.
8 p. m.	W.	W.	W.	nw.	nw.	nw.	W.	S.	S.	S.	W.	sw.	W.
9 p. m.	W.	W.	W.	nw.	nw.	nw.	S.	S.	S.	S.	W.	sw.	S., W.
10 p. m.	W.	W.	W.	W.	W.	S.	S.	S.	S.	S.	S.	sw.	S.
11 p. m.	S.	W.	W.	W.	S.	S.	S.	S.	S.	S.	S.	S.	S.
12 night	S.	W.	W.	S.	S.	S.	S.	S.	S.	S.	W.	S.	S.
Means	S.	W.	nw.	nw.	nw.	nw.	S.	S.	S.	S.	S.	S.	S.

WIND SHIFT IN THE LOWER THREE KILOMETERS OF THE ATMOSPHERE ON THE PASSAGE OF A HIGH.

By WALDEMAR NOLL, Proof Assistant.

[Dated Aberdeen Proving Ground, Md., July 29, 1919.]

A pilot-balloon observation made on the evening of July 8 showed an east-northeast wind in the lower regions which higher turned counter clockwise until it was northeast at 1,600 meters, directly north at 2,900 meters, and north-northwest at 4,000 meters. (Fig. 1.) The sky was cloudless except for the presence of a few Cu. On July 9, at 6:45 a. m., seventy-fifth meridian time, a few St.Cu. were rising over the horizon in the north and northeast, and in the foreground, toward the northeast, a small patch of Fr.Cu. was traveling from the west.

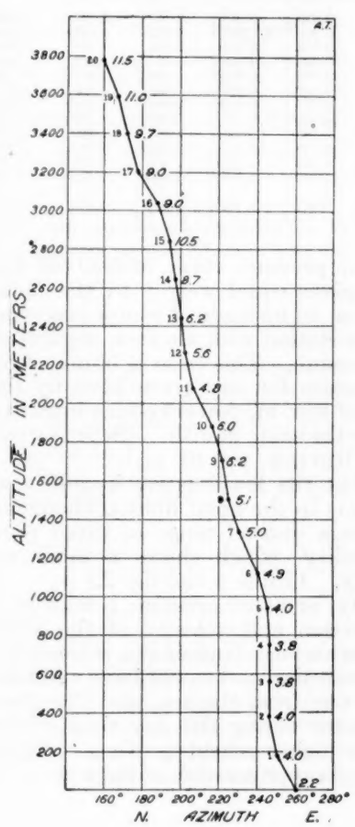
At this time a pilot balloon run was made. (Fig. 2.) Upon release the balloon swung toward the west and then clockwise to the north and north-northeast. At the height of about 600 meters, the velocity of the balloon suddenly increased from 5 meters per second to 9 meters per second and headed directly toward the St.Cu. in the northeast, which were coming up very rapidly over the horizon. At the altitude of 1,500 meters, the balloon swung sharply to the east and was then in the layer of air which was carrying the patch of Fr.Cu. from the west. The balloon continued swinging to the right until at the height of 2,300 meters it was coming from the north-northwest. At this altitude the balloon disappeared in the St.Cu. cloud. Had it been possible to follow the balloon several minutes longer, it would undoubtedly have shown a north-northeast wind, the wind direction obtained by cloud observation. By this time 15 minutes had elapsed and the sky was seven-tenths covered with St.Cu., all coming from the north-northeast. These blew over in about 30 minutes leaving a practically clear sky with only a thin light layer of A.St. covering most of the sky. The sky soon clouded over again with a St.Cu. layer moving from the south, which was predominant the remainder of the day.

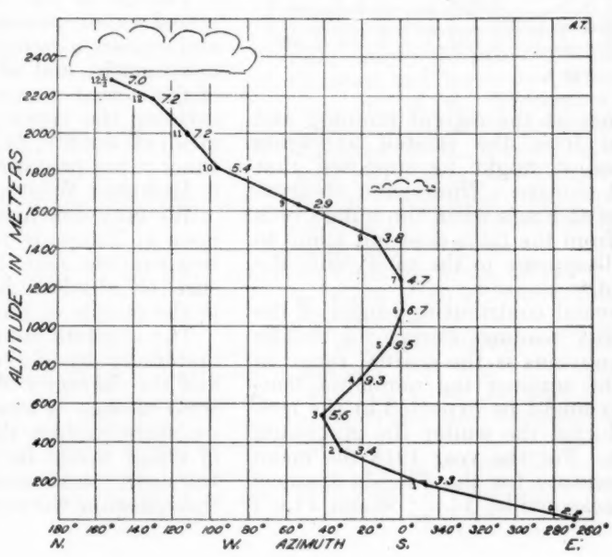
On the evening of the 9th southwest winds were blowing to a height of about 600 meters, and south winds from this height to 1,800 meters, the altitude at which the balloon disappeared into the St.Cu. then covering the sky. (Fig. 3.)

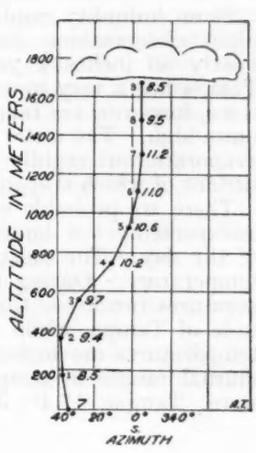
The weather map of July 9, 8 a. m., showed the axis of a HIGH extending over the middle and north Atlantic coast, with a maximum pressure of 30.38 inches at Atlantic City, Block Island, and Nantucket. A LOW was passing over the Canadian northwest, with a minimum pressure of 29.72 inches at Winnipeg, Man.

With the advance of this LOW during the night, a southerly wind, overriding a thin, cool, surface east wind, pushed in under the northerly wind of the anticyclone. In doing so an intermediate west wind was induced and heavy St.Cu. were formed largely by convection where the comparatively warm, west wind and the cooler northeast wind came into contact. Then the southerly winds kept on pushing up until the west wind was eliminated; and, apparently, when it came into contact with the colder northerly winds, St.Cu. formed, probably on the boundary, with at least their under surfaces in the south wind. These clouds were present for the remainder of the day.

FIGS. 1, 2, 3.—Altitude-direction graphs from pilot-balloon flights, July 8-9, 1919, at Aberdeen, Md.







DIURNAL VARIATIONS IN HUMIDITY.

By WALTER J. BENNETT, Meteorologist.

[Dated Weather Bureau, Tampa, Fla., July 29, 1919.]

Attention has recently been called to the low relative humidity readings at Tampa for the local mean noon observation. These for 1918 averaged considerably lower than at the other Florida stations and, in fact, corresponded more closely to the records of stations in the western plains. That this condition is a fact is shown by the consistency of the hygrograph records during the years 1915 to 1918. Moreover, many persons who have lived in the northern States have remarked that the high temperatures here are more comfortable than similar temperatures at the places from which they came. Table 1 gives relative humidity averages for the local noon observations at the Florida stations for the year 1918.

TABLE 1.

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Tampa	59	59	54	52	46	55	56	54	57	58	53	60	55.3
Jacksonville	59	68	60	58	55	59	60	57	62	72	65	72	62.2
Miami	61	69	62	63	65	69	69	68	72	74	63	68	66.9
Key West	70	69	63	66	67	68	66	65	68	74	65	71	67.8
Pensacola	71	78	74	78	71	66	69	74	70	81	73	76	73.4

Data obtained from bihourly hygrograph records being available from August, 1914, to December, 1918, diagrams and tables have been prepared in the same shape as figures 1, 2, 3, 4, and 5, and Table 4, of SUPPLEMENT No. 6, MONTHLY WEATHER REVIEW, and so a comparison may be made. None of the stations given in Table 4, SUPPLEMENT 6, is in the South, and the only one on the seacoast is San Francisco, which has an entirely different climate from Tampa. For this reason the data for Tampa should be an important addition to our knowledge of humidity conditions.

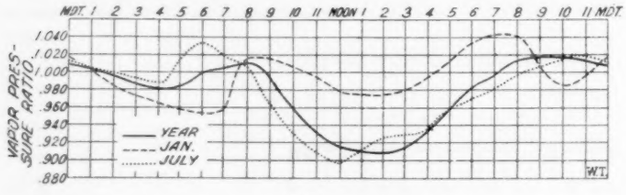


FIG. 1.

From humidity readings at the regular morning and night observations, and from the rainfall averaging nearly 50 inches a year, it might be supposed that Tampa has a very moist climate. The regular observations, however, are taken at hours when the humidity is quite high. The water from the rains does not stand to evaporate, but rapidly disappears in the sandy soil, the surface of which is soon dry.

There are probably several contributing causes of the unexpectedly low humidity readings during the middle of the day. The most obvious is the diurnal range in temperature. During the summer the minimum temperatures run lower than might be expected in the latitude of Tampa, while during the winter the maximum temperatures are higher. For the year 1918 the mean diurnal ranges in temperature for the Florida stations were: Tampa, 17.4°; Jacksonville, 14.8°; Miami 11.6°; Key West, 10°; Pensacola, 12°. Other things being equal, the greater the range in temperature the greater will be the range in relative humidity, and the lower will be the readings near the time of maximum temperature.

The greater range in temperature at Tampa, is partly due to the low elevation of the thermometers. At Tampa the height is 79 feet above ground; at Jacksonville, 209 feet; at Pensacola, 149 feet. At Miami the elevation is 71 feet, and at Key West only 10 feet, but Miami has the ocean in the direction of the prevailing, and nearly constant, wind, while Key West is surrounded by water. Hence the range in temperature at these two stations is lessened by oceanic influence.

The minimum temperature is largely determined by the dewpoint. At Tampa the average dewpoint taken from the regular a. m. and p. m. observations for 30 years, is less than a degree below the average minimum temperature. If the dewpoint and the vapor pressure (obtained directly from it), did not change during the day, the low relative humidity in the middle of the day would be completely explained by the range in temperature. But there is actually a fall not only of the relatively humidity, but also of the absolute humidity as shown by the vapor pressure. Of course, the lower the vapor pressure, the lower will be the relative humidity, the temperature being the same. There is also a fall at some of the other Florida stations, but the fall at Tampa is much greater, as shown by Table 2.

TABLE 2.—*Vapor pressure ratios (vapor pressure at local mean noon observation divided by mean vapor pressure at a. m. and p. m. observations) year 1918.*

	Tampa.	Jackson-ville.	Miami.	Key West.	Pensa-cola.
January	0.980	0.978	1.027	1.033	1.039
February	0.996	1.045	0.992	1.003	1.007
March	0.943	0.977	0.996	1.008	1.010
April	0.929	0.952	0.977	1.033	1.012
May	0.886	0.904	0.998	1.046	0.939
June	0.907	0.923	0.991	1.020	0.977
July	0.927	0.949	0.983	1.025	0.996
August	0.929	0.917	0.994	1.010	1.010
September	0.942	0.925	1.024	1.000	1.039
October	0.938	0.947	1.021	1.010	1.040
November	0.967	1.005	0.965	0.986	1.055
December	1.019	1.028	1.023	1.024	1.051
Year	0.947	0.962	0.999	1.016	1.015

The use of the vapor pressure ratio instead of the actual vapor pressure gives equal weight to the data. and enables a comparison to be made of winter and summer months, and of one station with another, regardless of the actual vapor pressure. This ratio is obtained by dividing the vapor pressure for any given hour by the mean of the 8 a. m. and 8 p. m. (seventy-fifth meridian time) vapor pressure for the same month. (SUPPLEMENT 6, MONTHLY WEATHER REVIEW, pp. 10, 11.)

We may conclude that the low relative humidity at noon at Tampa is due (1) to the great diurnal change in temperature, and (2) to a diurnal range in vapor pressure or absolute humidity, which shows a minimum in the middle of the day. (Table 4 and fig. 2.)

The absolute humidity, or vapor pressure, is influenced materially by the direction and velocity of the wind, and the character of the surface, land or sea, whence the wind blows. A wind from the land would have a smaller moisture content than one from the sea, and the effect of either would be greater during the day than during the night, on account of higher velocity. To investigate this question, the average vapor pressure at noon observa-

tions in 1918, was tabulated in connection with the prevailing wind direction from 11 a. m. to noon, the noon observation coming at 11.30 a. m., ninetieth meridian time. In this tabulation, January, February, March, and December were considered as winter months, and June, July, August, and September as summer

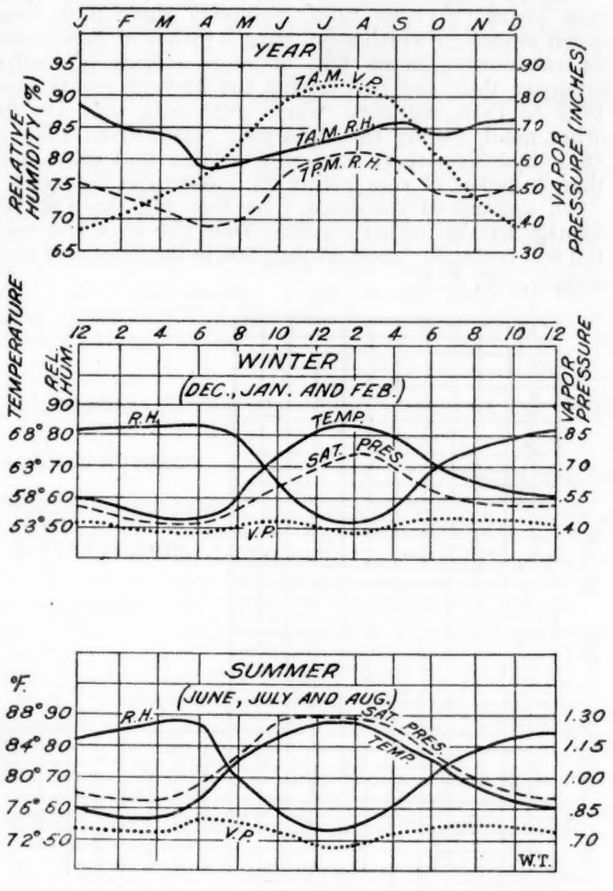


FIG. 2.

months. The frequency of each direction was calculated as a percentage of the total number of observations.

TABLE 3.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.
Winter:								
Mean vapor pressure...	0.277	0.253	0.486	0.518	0.535	0.512	0.409	0.285
Per cent of direction...	12	11	9	10	31	12	3	12
Summer:								
Mean vapor pressure...	0.619	0.637	0.669	0.700	0.706	0.720	0.743	0.667
Per cent of direction...	4	27	6	10	20	29	2	2
Year:								
Mean vapor pressure...	0.372	0.541	0.563	0.607	0.592	0.642	0.464	0.369
Per cent of direction...	7	24	8	9	24	18	4	6

Tampa is so situated that winds from the southeast, south, southwest, and west come from off water surfaces. The table shows that these winds have a greater moisture content than the winds from the other directions, and it also shows that they were slightly more frequent for the noon hour, being recorded 55 per cent of the time. At Miami and Pensacola, the winds are reported to be from off the water 90 per cent of the time, and at Jacksonville, although the percentage is not so great as that, it is considerably greater than at Tampa. Moreover, the winds are of greater force at the other stations, the average wind velocity for the noon hour at Tampa being 8 miles per hour; at Miami 11; at Pensacola 13; and at Jacksonville 13. The greater frequency and higher velocity of the ocean wind at the other stations might account in part for their greater humidity.

However, examination of the prevailing wind directions at all hours of the day at Tampa, shows that ocean winds are considerably more frequent during the middle of the day than at night, and if continental winds were the sole cause of the lower vapor pressure, the minimum might be expected to occur at night rather than during the day.

The diurnal march of vapor pressure at Tampa (Table 4 and fig. 2) shows a curve with two maxima and two minima. For the year as whole, the curve is quite smooth, showing maxima at 8 a. m. and 10 p. m., and minima at 4 a. m. and 2 p. m. The extreme range in actual vapor pressure is 0.062, which is 11 per cent of the average vapor pressure for the 12 bihourly means. The January curve shows maxima at 8 a. m. and 7 p. m., and minima at 6 a. m. and 10 p. m., the a. m. minimum being the lower in this case. The curve for July shows maxima at 6 a. m. and 10 p. m., and minima at 4 a. m. and 12 noon, the noon minimum being by far the lower.

Careful examination of the vapor pressure data for the different stations given in Table 4, SUPPLEMENT 6, brings out the following facts:

At Boise, Idaho, from March to September, the lowest vapor pressure values are at 4 or 6 p. m., the highest temperature occurring at those hours. At Burlington, Vt., from May to September, there is a slight fall, or secondary minimum of vapor pressure, at noon or 2 p. m., the highest temperature being at 2 p. m. At Fresno, Calif., the primary minimum of vapor pressure from March to October occurs at 6 p. m., the highest temperature being at 4 p. m. The afternoon minimum in July is particularly well marked, the vapor pressure ratio at 10 a. m. being 1.212, and at 6 p. m. 0.917. At Chicago, Ill., there is a weak secondary minimum at 2 or 4 p. m., from June to September, the highest temperature being at 2 p. m.

Grand Rapids, Mich., shows minima at noon or 2 p. m. from May to September, the minimum in July being lower than the night minimum. The highest temperature occurs at 2 p. m. St. Louis, Mo. shows a very faint secondary minimum in June and August at 4 or 6 p. m., the highest temperature being at 4 p. m. San Francisco, Calif., shows the primary minimum at noon in September, October, and November, with the highest temperature at noon or 2 p. m. September and October at San Francisco have higher temperatures than June, July, or August. Sheridan, Wyo., shows a secondary minimum at 2 p. m., May to October, the highest temperature being at 2 or 4 p. m. Springfield, Ill., shows a secondary minimum at noon or 2 p. m. in June and July, the highest temperature being at 2 p. m.

Columbus, Ohio, alone, of the 10 stations given shows no trace of an afternoon minimum of vapor pressure in any month.

Complete data are not available for the other Florida stations, but the vapor pressure ratios for the noon observations of the year 1918 are below unity in many cases (Table 2), indicating a midday or afternoon minimum.

Although evaporation is most rapid during the middle of the day, it would seem that there is a general tendency

toward a minimum of vapor near the time of maximum temperature, especially during the warmer months of the year, but the question is much complicated by evaporation and variations in wind velocity and direction, so that the afternoon minimum is often reduced, obliterated, or even turned into a maximum.

The only thing that could cause an actual decrease in the total amount of vapor in the air during the middle of the day is cloudy condensation, which is most active at that time. But this would be a very small factor.

Vapor pressure normally decreases with increase in altitude rather rapidly. (MONTHLY WEATHER REVIEW, March, 1919, p. 160.) During the heated portion of the day, especially in the warmer months, convection is quite active, and results in mixing the surface air with the drier air above. This mixing also brings down with the air from above, some of the momentum of the upper-air currents, and results in higher wind velocity during the day, and a turbulence of the atmosphere. This mixing by convection and turbulence is probably the true reason for the depression of the vapor pressure in the middle of the day. Observations aloft would probably show a rise in vapor pressure in the middle of the day, just as the wind velocity aloft is diminished thereby.

INTENSE RAINFALL AT DUBUQUE, IOWA, JULY 9, 1919.

Mr. J. H. Spencer, meteorologist, in charge of the Dubuque Weather Bureau office, has sent us an account of a very intense rainfall which accompanied a local thunderstorm July 9, 1919. In spite of the intensity of the rainfall, "thunder and lightning were rather less severe than in some of the storms of the past eight years," and the wind velocity was light.

"At no time during the hours that preceded the period of heaviest rainfall was there much indication of a severe storm, although the weather in the morning quickly changed to warm and sultry. Rain began as a light thundershower from 10:25 a. m. to 10:55 a. m. (ninetieth meridian time). Rain began again at 11:15 a. m. and was moderately heavy until 1:50 p. m. (the total to this time exceeding 1 inch). Then followed the great downpour of 2.64 inches in 45 minutes from 1:51 p. m. to 2:36 p. m.

"The following table gives the heaviest rainfall in periods of 5 minutes, 10 minutes, 15 minutes, 30 minutes, 1 hour, and 2 hours for a number of storms. It shows how much heavier was the rainfall on July 9, 1919, within a 1-hour period, than during any storm at Dubuque in recent years:"

Storm of—	5 minutes.	10 minutes.	15 minutes.	30 minutes.	1 hour.	2 hours.	24 hours.
July 4–5, 1876						[1] 4.55	4.55
Aug. 10–11, 1911	0.32	0.52	0.62	0.81	1.12	1.97	3.75
Aug. 18–19, 1912	.50	.71	.94	1.46	1.95	2.62	5.23
Aug. 31–Sept. 1, 1914	.41	.72	1.03	1.30	1.68	1.96	3.18
Sept. 14–15, 1914	.34	.51	.58	.73	.85	1.26	3.38
Sept. 25–26, 1915	.34	.46	.53	.68	1.27	2.23	4.79
Aug. 16–17, 1918	.35	.62	.79	1.37	2.10	2.96	5.22
July 9, 1919	.80	1.20	1.52	2.23	2.70	3.03	3.87

[1] 2 hours 5 minutes. 40 persons were drowned as the result of this storm.

Figure 1 shows the intense rainfall of July 9, 1919 (dotted line), in relation to other excessive rates in the North Central States plotted by Prof. A. N. Talbot.[1]

[1] Rates of maximum rainfall, Technograph No. 6, University of Illinois, 1892, 15 pp., incl. 8 diagrams.

The dashed curve A represents rates of rainfall which are rarely exceeded in the eastern United States. Its equation is $y=6.0/(x+.5)$, where y is the rate of rainfall in inches per hour for the time x expressed in hours. Curve B expresses the rate of frequent occurrence: $y=1.75/(x+.25)$.

"It is worthy of note that at Dubuque during the past nine years (1911 to 1919, inclusive) there have been seven storms in which more than 3 inches of rain within 24 consecutive hours fell, or more storms of similar intensity than occurred during the 29-year period from 1882 to 1910, inclusive, which gave only six. On the other hand, during the eight-year period from 1874 to 1881, inclusive, there were nine storms that gave more than 3 inches of rain within 24 consecutive hours."

An account of the seven lives lost and the $125,000 damage by the freshet resulting from this excessive rainfall will be found below on page 506 in the river and flood section.—*C. F. B.*

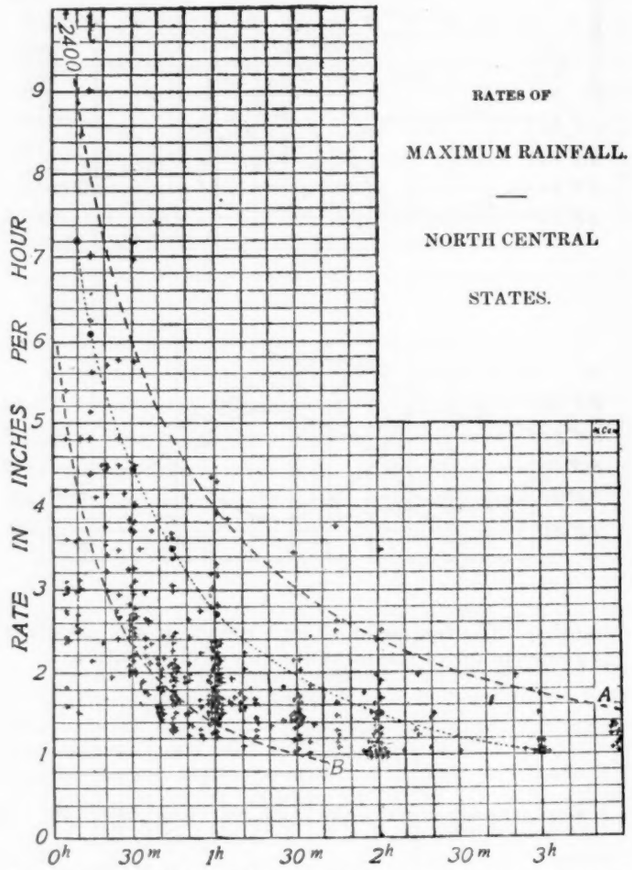


FIG. 1.—Excessive rainfall at Dubuque, Iowa, July 9, 1919, dotted line, compared with other excessive rates in North Central States. Compiled by A. N. Talbot.

HEAVY RAINS AT TAMPICO, MEXICO, JUNE 29–JULY 5, 1919.

By S. A. GROGAN.

[Dated Tampico, Tamaulipas, Mexico, July 7, 1919.]

During the week of June 29 to July 5, inclusive, more rain fell at Tampico than during the entire first six months of the year. From 6:30 a. m. on the 29th to 6:30 a. m. on the 5th a total precipitation of 15.64

inches was recorded. During the first 72 hours of the month of July 14.06 inches of rain fell in this vicinity.

The greatest 24-hour fall during that time was 8.36 inches from 6:30 a. m. on the 3d to 6:30 a. m. on the 4th. Of that, 3.55 inches fell from 6:30 a. m. to 6:30 p. m. on the 3d, and 4.81 inches fell during the night that followed.

The heaviest previous 24-hour rainfall since October, 1917, was on January 23, 1919, when a total precipitation of 2.23 inches was recorded. Our highest record in any month was 5.95 inches, during August, 1918.

There has been very little rainfall in this region during the past two years. I have no complete record for the year 1917, but the precipitation during the year 1918 was only 19.53 inches, with a total of 77 days upon which 0.01 inch or more fell. The 1918 precipitation is very likely a minimum record for several years in this vicinity, as I am of the opinion that the normal rainfall for Tampico and northern Vera Cruz is at least two or three times more than 19.53 inches. I also believe that the precipitation on July 3 of this year is a maximum 24-hour record for several years.

As may be seen from the data given below, this last excessive rain came from the east and northeast, and there was no break until the wind went to the west.

Meteorological record at Tampico, Mexico, June 29 to July 5, 1919.

[Observations at 6:30 a. m. (Tampico time) on dates given.]

Date.	Temperature.			Pressure.		State of weather.	Wind from.	Other observations.
	Max.	Min.	Mean.	Max.	Min.			
June 30..	90.5	79.5	85.0	29.88	29.82	cldy.	se.	0.14 in. rain.
July 1...	88.5	73.5	81.0	29.92	29.84	cldy.	sw.	0.98 in. rain.
2...	83.0	72.0	77.5	29.93	29.85	cldy.-rain.	ne.	2.88 in. rain.
3...	79.0	72.0	75.5	29.85	29.81	cldy.	e.	2.82 in. rain.
4...	77.0	71.5	74.3	29.86	29.80	cldy.	ne.	8.36 in. rain.
5...	79.5	72.5	76.0	29.90	29.80	cldy.	sw.	0.46 in. rain.
6...	87.0	73.0	80.0	29.92	29.88	cldy.	w.	0.00 in. rain.

Total rainfall this week.....inches.. 15.64
Total rainfall this month to date.....do.... 14.5
Total rainfall this year to date.....do.... 27.26

NOTE.—The above pressure data are shown as recorded by our recording barometer; the temperature as shown by standard maximum and minimum thermometers; and the rainfall as measured in a common rain gage.

NORTHERS ON THE EAST COAST OF MEXICO, THEIR EFFECTS, AND FORECAST BY LOCAL OBSERVATIONS.

By S. A. GROGAN.

[Dated Tampico, Mexico, July 9, 1919.]

With the exception of the tropical storms during the summer months, there is no other weather which causes more concern among the navigators on the Gulf of Mexico than do the northers along the east coast of Mexico from about the 1st of September to the latter part of April. From September, 1918, to June, 1919, 31 northers visited Tampico.

Few records show of any ships being lost in the open sea from the effects of these north winds, but many have suffered serious damage or have been entirely lost from being blown up on the coast or the breakwaters at the entrances to the ports. No records have been obtained previous to 1917, but during that year there were seven disasters in the vicinity of Tampico, which can be attributed to northers.

Mr. Wm. J. Pulford, Lloyd's agent at Tampico, has been so kind as to furnish me with the following list of disasters for that year:

March 18, American tanker *Winnifred* went ashore south Tampico breakwater. Refloated on March 23 and towed to the United States for repairs.

May 17, American barge *Vaska* went ashore and lost north of Tampico breakwater.

October 20, American schooner *El Gallo* went ashore south of Tampico. Became a total loss.

October 30, American tug *Southbay* foundered outside Tampico breakwater.

October 31, American tanker *Paddleford* driven ashore south Tampico breakwater. Floated the following spring and taken to the United States for repairs.

November 15, American tug *Relief* went ashore north of Tampico. Floated on November 17.

December 8, American steamer *Wellington* drifted ashore in heavy norther. Sustained general damage to hull, rudder, etc.

While no lives were lost in any of the above disasters they occurred at a time when there was a general demand for more ships. Of the above, the tanker *Paddleford* was probably the greatest loss. Although it was floated in the following spring, it was taken from its important duty of conveying oil to the United States during the time it laid up on the breakwater and it was being repaired in the States.

During the first part of the year 1918 the schooner *Veracruz* was blown ashore on the south breakwater.

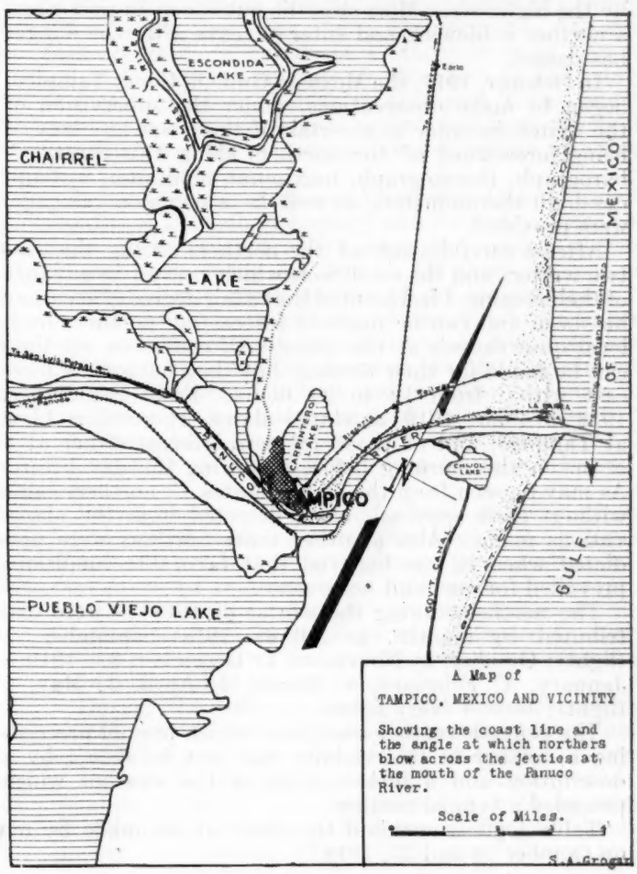


FIG. 1.

On January 22, 1919, the tug *George* left port late in the afternoon with a barge of oil to be taken outside the bar. A norther was blowing at the time, and although the out-

ward trip was made without mishap, upon its return the boat was thrown out of the channel and upon the south breakwater. Thirteen lives were lost in that accident, among whom were the two pilots, and the tug was a complete loss.

Probably the hardest norther of the winter of 1918–19 blew during the afternoon and night of February 26, 1919. Although we had no anemometer to determine the velocity, it was probably about 50 miles per hour. It was strong enough to blow down fences, remove sheet-iron roofs and to make walking in the street very difficult. No damage was done to shipping in the vicinity of Tampico, but several losses were reported among the sailing vessels of the fishermen near Vera Cruz.

The greater part of the losses on the Tampico breakwater have probably been due to poor judgment on the part of the captains or to their ignorance of the conditions which exist at that place during a norther.

Figure 1 shows a map of Tampico and vicinity, and by consulting this it may be seen that the Panuco River empties into the Gulf of Mexico in an east-northeastern direction. The prevailing direction of the northers in this vicinity is from the north-northwest, or at right angles to the direction of the flow of the river. For that reason the difficulty in passing through the jetties when a norther is blowing is easily realized. The breakwater was begun a short time before the revolution and was never completed. Both the outer points are completely submerged and other places further in have been damaged by the high seas. Most ships lie outside or in port when a norther is blowing and enter or leave after the danger has passed.

In October, 1917, the Mexican Gulf Oil Co. at Tampico, began to make observations, under the supervision of the writer, in order to ascertain if there was any way of being forewarned of the northers along this coast. A barograph, thermograph, maximum, minimum, wet and dry-bulb thermometers, as well as a common raingage, were provided.

After a careful study of the northers during the past two winters and the conditions which prevail in advance of their coming, I feel assured that a fair degree of accuracy has been and can be made in forecasting northers from local observations at this place. Of course no set time can be made for their coming, but they have been forecast within from 12 to 24 hours. From September, 1918, to June, 1919, as stated above, 31 northers blew at Tampico, and of those 18 were forecast either at 8 a. m. on the morning before or during the day before. As may be seen from the above figures, 13 northers came without their approach being detected from the observations made. Also at other times northers were predicted when it was believed that favorable conditions prevailed for one, and none came.

The northers during the winter of 1918–19 were distributed by months, as follows: 1918—September, 1 (light); October, 2; November, 4; December, 3. 1919—January, 4; February, 8; March, 4; April, 3; May, 1 (light); June, 1 (very light).

The general weather conditions which prevail preceeding a norther in this vicinity can best be shown by a description and a meteorogram of the weather which preceded a typical norther.

Table 1 gives in detail the observations made by me on October 26 and 27, 1918:

TABLE 1.—*Weather observations, Tampico, Mexico, Oct. 26 and 27, 1918.*

Observation of—	Tampico time.			
	Oct. 26.		Oct. 27.	
	6:30 a. m.	6:30 p. m.	6:30 a. m.	6:30 p. m.
Dry thermometer	78° F.	81° F.	65° F.	71° F.
Wet thermometer	77° F.	79° F.	54° F.	58° F.
Dew point	77° F.	78° F.	45° F.	48° F.
Relative humidity	96 per cent.	92 per cent.	48 per cent.	45 per cent.
Vapor pressure	0.926 inch.	0.957 inch.	0.298 inch.	0.334 inch.
Barometer	29.72 inches.	29.66 inches.	29.98 inches.	30.01 inches.
Maximum temperature	80° F.	92° F.	81° F.	74° F.
Minimum temperature	77° F.	78° F.	64° F.	65° F.
Maximum pressure	29.84 inches.	29.73 inches.	29.98 inches.	30.04 inches.
Minimum pressure	29.70 inches.	29.62 inches.	29.66 inches.	29.98 inches.
State of weather	Cloudy.	Part cloudy.	Cloudy.	Cloudy.
Wind from	S.	E.	N.	N.
Precipitation	0.02 inch.	None.	0.02 inch.	None.

During the 24-hour period ending at 6:30 a. m. on October 26, 1918, the air pressure reached a minimum of 29.70 inches during the afternoon of the 25th, and with the exception of the slight diurnal rise in the fore part of the night, there had been very little change up to that hour. The wind was from the south; it was cloudy, the temperature 78° F., and the relative humidity 96 per cent. During the day of the 26th the pressure continued to drop until it reached 29.62 inches at 3:30 p. m., the wind had changed to the east and a maximum temperature of 92° F. was recorded at 2 p. m. At 6:30

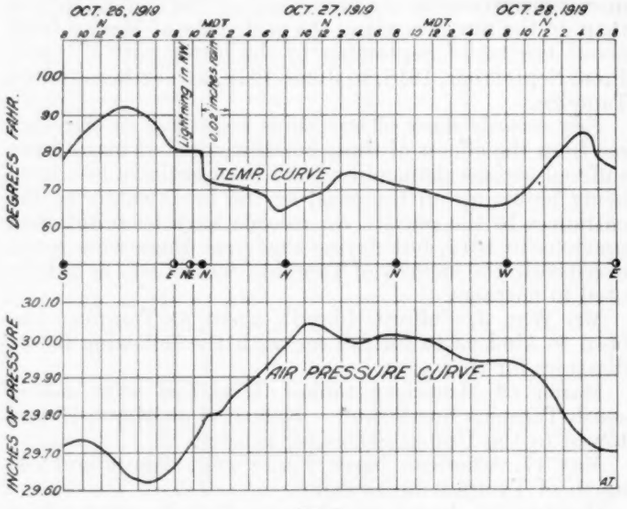


FIG. 2.

p. m. the wind was still from the east, the temperature 81° F., relative humidity 92 per cent, and the sky was partly cloudy. As soon as darkness had come, lightning was observed in the north and northwest. At 8 p. m. the cloud was in plain view in the northwest and the electrical display was vivid. Since 3:30 p. m. the air pressure had been rising and at that hour had reached 29.71 inches. At 9:30 p. m. the storm struck with a light precipitation of 0.02 inch, and was followed by a stiff north wind.* This norther was forecast at 8 a. m., October 26, to come within the next 24 hours, as near as could be judged. A study of the weather map for 8

* The front of this norther was similarly well-defined in Texas.—C. F. B

a. m. on that date reveals the actual conditions as existed in the western part of the United States.

Figure 2 shows the tracings from the thermograph, corrected to the thermometer readings, and from the barograph here, from 8 a. m. (seventy-fifth meridian time), October 26 to 8 p. m., October 28, 1918.

The norther, given as an example, came in the early part of the night, but the greater part of them come from 2 to 4 a. m. However, the phenomena preceding this one is typical and the description of the weather preceding a typical norther in this vicinity can be expressed in the following general terms:

There is a very low air pressure during the afternoon before (usually about 29.60 inches) after which it begins to rise gradually until the norther begins to blow, there is a high maximum temperature, high relative humidity, very often a heavy dew in the first part of the night, at times a fog on the morning before, the wind backs from south to northeast and lightning is generally to be seen in the northwest. The first part of the blow is usually accompanied by a light rainfall and there is a general cloudiness throughout the entire time the norther blows.

The northers are not always typical, but at times blow up when there has been no warning by the air pressure and the other phenomena, as given in the example, and very often they repeat within a few hours' time.

It can be seen that the only method that can be used in making a forecast of a norther in this vicinity is from a comparison of the conditions at any time with those which occurred before a typical norther came, and if the conditions are similar the probability of a norther is very good, as I have found.

The writer feels that until some better means of knowing the coming weather can be provided for Tampico and the east coast of Mexico, our efforts are not in vain. On several occasions light craft have been held in the port by being warned that a norther was very likely to blow within the next 24 hours. The captain of the port of Tampico, wired our daily reports to Vera Cruz during the winter months and words of appreciation have been received from that important port.

FOG IN CENTRAL OHIO AND ITS RELATION TO SUBSEQUENT WEATHER CHANGES.

By HOWARD H. MARTIN, Observer.

[Dated Weather Bureau Office, Columbus, Ohio, May 26, 1919.]

Fog is a meteorological phenomenon. It is the direct result of the depression of the air temperature to a point equal to or lower than the existing dew point. This depression may be brought about by radiation and conduction, cooling by atmospheric expansion, or by the mixing of cold and warm, humid air. Fogs due to radiation occur for the most part over valleys and low ground after a warm afternoon. Those due to cooling by expansion are rarely local, but may cover relatively vast areas. Inland fogs due to mixing usually occur at or near the wind-shift line during the passage of a cyclonic area. Such fogs are uncommon in Ohio, and when they do occur, usually precede a rapid and severe drop in temperature.

All fogs may be classified into (1) radiation fogs, those fogs due to radiation in quiet air and (2) advection fogs, those general fogs due to cooling by conduction, radiation, mixing or expansion in horizontally-moving air. Radiation fogs occur for the most part during the late spring and summer months, are very local and without apparent significance. Advection fogs, being due to air movements, often are indicative of weather changes. These fogs occur during the winter and the early spring months, usually with clouds, and precede a marked rise or fall in pressure by from 6 to 30 hours. It is well to discriminate here, though not in the general classification, between the fogs near or in low pressure centers or troughs, and the fogs immediately in the rear of an anticyclone. The former occur practically at the center of the disturbance, during a temporary lull in the wind. and, of course, are dissipated by the colder, drier winds from the west; the latter often occur during the prevalence of high pressure and appear to be the first symptom, if such a term is permissible here, of an immediate decrease in atmospheric pressure. Of 44 dense fogs recorded under these conditions, 38, or 86 per cent, were followed immediately by decreasing pressure (within 12 hours) and 92 per cent, by falling barometer within 24 hours.

The records of the Weather Bureau Office at Columbus (Ohio) show that from 1900–1918, inclusive, 144 dense fogs occurred. Previous to a study of these fogs, the writer had given considerable attention to the relation of fogs to weather changes in northeast Texas, and the results are comparable, bearing out, to a large degree, the significance of the phenomenon in connection with subsequent precipitation.

It has been found that at Columbus, Ohio, during the months of December, January and February, 1900–1918, dense fogs occurred on 76 days, the average duration in each case being 3.8 hours. Of these, 43 per cent occurred during precipitation; 67 per cent preceded rain or show by 24 hours or less; 83 per cent by 36 hours or less; and 90 per cent by rain or snow within 48 hours. Of the entire number observed during these months, 92 per cent were followed within 24 to 30 hours by a marked pressure change, and of these changes, 69 per cent were falls, 19 per cent increases, 10 per cent falls followed by rises and 2 per cent by rises followed by falls.

During the months of March, April, and May, 22 dense fogs occurred, with an average duration of 2.7 hours, and of these 29 per cent occurred during precipitation, 40 per cent preceded rain or snow by 24 hours or less; 76 per cent within 36 hours, and 80 per cent within 48 hours. Of these 22 fogs, 76 per cent were followed by marked pressure changes within 24 hours, of which 59 per cent were falls, and 41 per cent rises.

During the summer months, the few dense fogs on record, total 5, were all radiation fogs, and hence had no apparent significance with relation to coming changes.

During the months of September, October, and November, 41 dense fogs were recorded, with an average duration of 4.2 hours. Of these, 17 per cent occurred during precipitation, 39 per cent were followed by rain or snow within 24 hours, 53 per cent within 36 hours, and 66 per cent within 48 hours. Of the number recorded, 63 per cent were followed by marked pressure changes, of

which 50 per cent were falls, 35 per cent increases, and 15 per cent falls preceding increases.

Thus, it may be readily seen that, in central Ohio, for the year (June, July, and August, excluded), 50.8 per cent of all observed dense fogs are followed by rain or snow within 24 hours; that 68.7 per cent precede precipitation by 36 hours or less, and that 78.6 per cent are followed by rain or snow within 48 hours.

To reduce these apparent values to the true prognostic values, it is necessary to determine first the frequency with which a class of variable events wholly unrelated to weather would be followed by precipitation within the prescribed number of hours. Since the 48-hour values are by far the higher, these only will be considered. The writer has determined the frequency with which the hour of sunrise has been followed by precipitation, and by application of the simple formula

$$\frac{P-p}{100-p}=V$$

where P is the apparent percentage of verification, p the percentage possible by chance, as determined above, and V the true prognostic value, the apparent 48-hour percentages are reduced to represent the actual prognostic value.

The hour of sunrise in winter was followed by precipitation within 48 hours on 61 per cent of the total number considered; the apparent 48-hour percentage of verification is thereby reduced from 90 per cent to 74 per cent. Sunrise in spring is followed by rain or snow within 48 hours in 60 per cent of the total cases recorded, which reduced the apparent value of verification 80 per cent to 50 per cent. In autumn, precipitation has followed sunrise within 48 hours on 43 per cent of the occasions, thus reducing the apparent verification 66 per cent to 40 per cent. For the year, summer months excluded, rain or snow follows sunrise within 48 hours 55 per cent of all occasions, and the yearly percentage is thus reduced from 79 per cent to 54 per cent. Thus, the occurrence of fog has a true prognostic value.

There appears to be but little relation in central Ohio between the occurrence of dense fog and subsequent temperature changes, since even in the winter months, but 28 per cent of fogs were followed by temperature falls of 10° or more, while rises of similar degree followed 31 per cent. In the Spring, 55 per cent of the observed fogs were followed by a rise in temperature. In this connection, however, it is interesting to note that in northeast Texas the writer found that 82 per cent of advection fogs were followed by marked temperature falls within 24 hours and 88 per cent preceded such falls by 36 hours or less. From this it is apparent that the greater number of fogs in northeast Texas occurred at or near the windshift line of the passing cyclone, whereas in Ohio, the greater number occur before the oncoming storm has made itself otherwise manifest.

It was found in northeast Texas that the direction of the surface wind at the time of fog is an essential factor in determining the actual relation of the fog to ensuing weather. Thus, with light westerly winds, typical anticyclonic conditions, the prognostic value is greatly minimized; with upper clouds from a westerly direction, and with southerly winds, the fog was usually followed by precipitation within 10 hours, while with easterly winds, high pressure, and slowly rising temperature after a sudden fall, precipitation with marked falling pressure occurred within 18 hours. The wind factor is not of so much importance in central Ohio, since the southwest wind usually prevails throughout the winter months. However, it was found that of the 78.6 per cent of fogs followed by precipitation within 48 hours, 92 per cent occurred with southwest winds, 4 per cent with south winds, and 3 per cent with west winds.

The fog has, from time to time, been recognized in adage and proverb as a possible indication of coming weather changes. In Texas, for instance, it is common to hear the saw, "A winter fog will freeze a dog," the dog in question probably being of the Mexican hairless variety, very susceptible to cold. Along the Pacific coast, it is said that three successive foggy mornings bring rain. It has been said that fog forming at night indicates rain; that of the morning, fair weather; that a rising fog promises clear skies, while a settling fog foretells storm. All these have, perhaps, long periods of observation to bear them out, and in many cases are based on sound meteorological laws. Yet, on the whole, it is better to consider the fog only as a physical result of a combination of meteorological conditions, essential to condensation, and favorable to precipitation.

DISCUSSION.

To get the true value of any phenomenon as a prognostic of rain, for example, the percentages should be compared with those obtainable from the use of a phenomenon unrelated to the occurrence of rainfall. For periods of whole days, the time of sunrise may be used, as Mr. Martin did; but it may be worth while to consider a method which may be applied generally. The percentages found from the tabulation of the phenomenon of prognostic value may be compared with the percentages of the total time which occur during rainfall or within dry periods of differing length before the beginning of rainfall, and which, therefore, represent with what frequency rain would follow within a specified period after any occurrence unrelated to the weather.

Supposing we tabulated: (R) the time (in hours) during which rain has fallen; and the numbers of dry periods according to length, say, (A) 0–12, (B) 12–24, (C) 24–36, (D) 36–48, and (E) over 48, hours; and computed the whole time (T) in hours covered by the period investigated. Using the letters indicated to represent the items just mentioned, we could obtain the frequency with which rain would occur within 12, 24, 36, or 48 hours after any instant, by the following formulas:

Probability of rainfall within—

12 hours = [R + 12 ($\frac{1}{2}$ (A) + B + C + D + E)]/T.
24 hours = [R + 24 ($\frac{1}{2}$ (A + B) + C + D + E)]/T.
36 hours = [R + 36 ($\frac{1}{2}$ (A + B + C) + D + E)]/T.
48 hours = [R + 48 ($\frac{1}{2}$ (A + B + C + D) + E)]/T. —

Charles F. Brooks.

THE USE OF CLOUDS IN LOCAL FORECASTING.

By MERTON L. FULLER, Meteorologist.

[Dated Weather Bureau, Peoria, July 29, 1919.]

SYNOPSIS.—Cloud indications usually agree with those of the weather map, but often contribute additional information. For the longer forecast periods clouds seldom warrant a differing forecast. For shorter periods they are increasingly useful, especially in handling local inquiries during the day.

In formulating rules for cloud forecasting, but little assistance is to be expected from station records, since they omit the speed of clouds and make no distinction between types within the same class. Cloud indications differ in different sections of the country. In the upper Mississippi Valley, at least, certain combinations and sequences of cloud are nearly always followed by definite weather developments.

Various opinions have been expressed as to the actual or possible use of clouds in forecasting weather. For a number of reasons attention to clouds in local forecasting seems justified. Clouds are a visible, and the most conspicuous, stage in the cycle of evaporation and condensation of atmospheric water vapor, and, theoretically, should be of service in forecasting precipitation. The cloud sheet of a LOW is a feature of the weather map commonly considered by meteorologists in arriving at a forecast. Further local use of clouds would be only an extension of existing procedure. The local forecaster is expected to amplify or adapt the district forecast to meet the needs of his community. But except where topography influences weather, the local official has little or no information, outside the map, on which to base any "amplification," except such indications as his sky may afford. Moreover, the local forecaster is nearest the public and should naturally receive numerous inquiries regarding details of expected weather during the 10 or 12 hours immediately in advance—inquiries important to public interests but not covered by the map data, and concerning which the clouds often afford considerable information. In handling this class of inquiries lies one of the largest opportunities of the local official for service to his community.

But when the practical utilization of clouds in forecasting is undertaken, certain limitations and difficulties are encountered. Cloud indications, when present, usually agree with those of the map, though they often give further information. Their use in connection with the published forecasts is chiefly in corroborating or modifying other indications. For the longer periods covered by the published forecasts cloud indications seldom differ with sufficient definiteness from those of the map to warrant a differing forecast, though that sometimes occurs. For the shorter periods clouds become increasingly useful.

It is often difficult to use clouds in the a. m. forecast, because night breaks the continuity of the observer's acquaintance with sky conditions. And the rush of morning work, together with the early preparation of the forecast, frequently makes it impossible to gather up the sky threads in time for that use. This is partly overcome if the work schedule can be arranged to allow the local forecaster time enough for proper cloud observations beginning about sunrise. More use can often be made of clouds in the p. m. forecast where one is issued locally.

In working out definite rules or statements of cloud indications for forecasting, the study of station records appears to be of little direct service. Careful observers have doubtless noticed that some forms and movements of cirrus and cumulus are good indicators of rain, while other forms and movements of the same class of cloud are almost equally good indicators of fair weather. But most records unfortunately make no distinction between forms within the same class. The amount of cloud and the direction of movement are recorded, but the essential element of form or type and the sometimes equally important element of speed, are omitted. Therefore it is thought that statistical studies of cloud occurrence and subsequent weather, based on the usual records, can not be expected to assist beyond a preliminary stage.

The particular forms, movements, and appearances of clouds that are of value to the forecaster naturally differ more or less in different portions of the country, depending on the observer's location with reference to storm tracks, general wind system, the types and stages of storm development commonly experienced, and a number of other elements. The significant types can not readily be presented in description or diagram clearly enough to make their recognition always certain by an inexperienced observer. They must be learned, in part at least, by personal observation and experience before they can be used with confidence. The following notes summarize a few of the results of a study covering more than two decades and carried on in several States from the Plains to the St. Lawrence, but chiefly in the upper Mississippi Valley. They may perhaps be suggestive. No effort is here made to discuss the topics fully. The order is roughly that of cloud types rather than frequency of occurrence or value to the forecaster.

The most useful clouds to the forecaster are cirrus, cumulus, and their modifications.

Generally cirri, to be significant, should move rapidly, or at least at average speed. Cumulus and alto-cumulus may move either slowly or rapidly, depending on associated conditions.

Cirrus, or cirro-stratus, of the right type, either scattered or numerous, moving rapidly from the northwest (north-northwest to west-northwest) across the middle sky, are often followed by rain within 6 to 18 hours; but the clouds must be of the right type and sequence.

(*a*) Exception: If these cirri are the front edge of a cirrus sheet that is spreading from the west or southwest horizon over our sky, they may be connected with a distant western LOW, and our rain will be longer delayed. This occurs oftenest in winter or the cool months.

(*b*) If the cirri, especially in summer, are confined wholly to the lower northeast sky, the rain is likely to follow there and may not reach the observer. The arrangement and extent of the cirri, particularly on their border in the northwest sky, will sometimes indicate in such cases whether the rain will reach the observer. The application of this rule differs somewhat between Peoria and north-central Iowa.

Cirrus or Ci.St., of the right type and sequence, moving rapidly from points between west-southwest and south-southwest, indicate rain or snow next day about four-fifths of the time. Often the rain will begin early, sometimes before morning. If the cirri are present in the morning and thicken rapidly to the lower stratus levels by late forenoon, precipitation (at Peoria) may begin in afternoon of the same day.

(*a*) Exception: The northwest edge of a Ci.St. sheet belonging to a LOW that has passed to southeast of the observer may move rapidly from the southwest without being followed by precipitation. In Iowa even this combination is likely to be followed by at least a trace next day.

(*b*) Exception: But if, with such a LOW, the cirri lying across the south and southeast sky spread rapidly outward from the south and increase noticeably in density, it is an indication that the LOW is either moving or developing northward and may bring precipitation to the observer. This sometimes occurs when the morning pressure changes did not clearly indicate the northward turn of the LOW. If the LOW is too far east to affect the observer's locality, the successive arrangement of cirri in the southwest sky often shows that fact in advance. When the above movements of cirri from nearly south occur in the morning, precipitation usually follows by mid-afternoon.

Another type of cirrus, or Ci.St., from the southwest or west-southwest, shows by its successive forms and arrangement that rain will occur on the morrow, that it will usually begin before morning, and that the heaviest portion of the storm will pass to northwest of Peoria. This set of indications is seen at Peoria in front of many of the southwest LOWS that were headed toward the Ohio Valley or Tennessee, but turn northward during the day and later cross Iowa. The pressure changes of the morning map may, or may not, have shown this tendency.

In summer detached cirrus clouds appear two to eight hours or more ahead of a large share of the local storms. Often the arrangement of cirri indicates the portion of sky to be traversed by the heaviest portion of the storm. When cirrus plumes or streamers move endwise, or ths wisps and patches of Ci.St. persist, along the same line across the sky, then if there is any marked difference in density or number or in clearness of outline among those clouds, the heaviest portion of the storm will usually follow the path marked by the heaviest or clearest or most numerous cirri. This rule does not hold for Ci. streamers moving obliquely. Sometimes there are bars and streamers moving endwise and others in oblique position but moving in the same direction. In such cases the principal portion of the storm is likely to follow the streamers that move endwise.

Rapidly moving Ci. streamers from west or west-northwest, with or without focal points, when succeeded by broken clouds or patches of clear sky, usually indicate fair weather if the wind accompanying the cirri is fresh from the west; otherwise not.

Cirri from the west, with or without streamers, and streamers with or without focal points, may increase toward mid-afternoon. There may also be other clouds, A.St., Ci.Cu., or A.Cu.; the general cloudiness may break up between 3 or 4 p. m. and sunset, sometimes clearing almost completely. This sequence, with southerly or easterly winds, is an almost infallible indication of rain to begin before morning, often with thunder.

A.Cu., in summer, are one of the most useful rain indicators.

Detached A.Cu., from southwesterly (south to west) points, in the morning, nearly always mean thunder showers in afternoon, most frequently between 2 and 6 p. m. This may not hold just after another storm.

Detached A.Cu. from northwesterly points, in morning, are nearly as useful. Sometimes their rain comes quicker than that after A.Cu. from southwest.

Exception: Occasionally a wind shift or a sprinkle of rain comes with the morning A.Cu. When that occurs no afternoon developments may follow. Under such conditions the morning A.Cu. seem to mark the center of a disturbance that is passing eastward and produces no more showers for that locality. But when A.Cu. occur in morning without rain or wind shift, they are connected with a disturbed or unstable condition to westward that will usually develop Cu.Nb. in the stronger convectional overturn of afternoon.

A.Cu. often mark the paths of showers, or of the heaviest portions of more general thunderstorms, several hours (often four to eight) in advance. Sometimes this is done by detached groups of A.Cu. occurring only in certain portions of the sky or persisting along certain paths; at other times by the formation of lines or bars of heavier or denser development, that move longitudinally, persisting along certain paths. When such bars or lines move obliquely or laterally they do not have the same significance. When scattered bars move laterally, any subsequent associated rain is apt to be brief, and light in amount, unless other cloud indications at the time show otherwise.

In north-central Iowa there occurs a combination of clouds, chiefly cirri and A.Cu., in which A.Cu. cover one-fourth to one-half or more of the sky through midday and much of the afternoon; being preceded and attended by cirri, and clearing toward evening. This is invariably followed by active thunder showers between midnight and morning. The clouds are from westerly points. In a modified form of the combination they may move from the southwest, at least in Illinois. The Iowa combination seldom occurs at Peoria except with modifications.

In northern Iowa, after a clear summer day with southerly wind, the appearance of even a single bar of A.St., or a few fragments of A.Cu., near the northwest horizon at sunset, often indicates scattered showers next day; even though the evening weather map carries no rain in the northwest. The showers may be more or less general, and may arrive by early morning. The occurrence of that evening indication should put the forecaster on guard, unless the evening map shows plainly that no pressure wave is possible. This occurrence seems to be associated with some of the occasional high pressure waves of summer that traverse the north-central border States, without, as a rule, extending their influence very far south. The indication is seldom useful at Peoria.

Cumulus: When conditions favor the development of showers, the cumuli of morning or middle forenoon often show the paths to be followed by afternoon showers. In some seasons and in certain types of weather this indication has frequently been found useful, particularly in Iowa.

There are many cloud indications that will reward the attentive meteorologist with considerable assistance in serving his community.

HIGHWAY WEATHER SERVICE.

During the winter of 1918–19 the Highway Weather Service was in operation to a greater or less extent at some 23 stations in 13 States. At most of these stations, principally in the northern States, it was a winter service only and was discontinued in the spring to be resumed the coming winter. At a number of stations, however, the service has been continuous.

This Service, now entering its third season, consists mainly of the collection and distribution of information in relation to the condition of the main State highways and of the dissemination of warnings of expected cold waves and heavy rains or snows. At some stations that are corn and wheat region centers the information is obtained from such of the substation observers as are located on or near the main highways, a word to represent the road conditions, as "Good," "Passable," "Bad," etc.,

being added to the daily report. This addition, by an arrangement with the telegraph company, can be made without increasing the expense of the report. At some of the corn and wheat region stations referred to a column is added to the bulletin giving the road conditions, but in some cases where this is not feasible a separate card bulletin is issued. At other stations the information is obtained from correspondents who are furnished with franked postal cards and make daily reports by mail, the information contained thereon being summarized at the central station, published on the daily bulletins, and otherwise distributed. The mail reports are supplemented by reports by telephone or telegraph, at Government expense, as occasions may require, on the occurrence of unusual conditions. The correspondents are largely persons connected with State highway commissions or interested in automobile traffic, and serve without compensation.

AERIAL WEATHER FORECAST SERVICE IMPROVED.

[Reprinted from Aerial Age Weekly, New York, Aug. 18, 1919, p. 1048.]

WASHINGTON, D. C.—The Weather Bureau * * * has prepared a map of the United States divided into 13 zones, for which forecasts are to be made for aviators and balloon pilots. These forecasts are made twice daily, at 9:30 a. m. and 9:30 p. m., and cover conditions for the succeeding 24 hours.

Since July 21, forecasts have been made with the country divided into seven zones, with such satisfactory results that the number of zones has been increased to 13.

The Air Service has sent out the revised map to their active stations throughout the country and the forecast will be forwarded at the time made,[1] it being intended that all cross-country fliers shall be advised of the weather conditions before starting on any contemplated flight, thereby reducing * * * to a minimum the liability of injury to aviators, balloon pilots, passengers, and property, as far as weather conditions are concerned.

[1] It is expected that arrangements soon will be made for the press services to handle these forecasts, for publication in newspapers located in the regions where flying is more or less general.

PLANT TEMPERATURES.

[From Annual Report of the Director of Bureau of Standards, year ending June 30, 1916, pp. 92-93.]

As a result of inquiries by botanists and agronomists concerning the transmission, reflection, and temperature of growing leaves and methods for determining the same, experiments were made on methods of making temperature measurements with needle-pointed thermocouples of fine (0.05 mm.) wires inserted into the ribs or petiole of a leaf. Data on transmission and reflection have been published in Scientific Paper No. 196, Diffuse Reflecting Power of Various Substances. The temperature measurements are relative values, which fluctuate very rapidly with every breeze that blows. In quiet air, in the shade, the thick succulent stem of a burdock leaf was 3.5° C. below the room temperature (below the temperature of the water in which it stood), while the leaf was only 0.5° C. below. Similarly leaves of other plants were 0.2 to 0.5° C. below the room temperature. In the sun, however, conditions were different. The cooling by transpiration of water is not rapid enough in comparison to the rate of absorption of solar energy. The temperature of a growing plantain leaf exposed to the sun was 5 to 6° C. higher than the air temperature.

PRECEPTS FOR FORECASTING RIVER STAGES ON THE CHATTAHOOCHEE AND FLINT RIVERS OF GEORGIA.

By C. F. VON HERRMANN, Meteorologist.

[Dated Weather Bureau, Atlanta, Ga., Aug. 8, 1919.]

GENERAL SUMMARY.

Preliminary investigation has shown that there does not seem to be a very definite correlation between the river stages at upper and lower river stations on the Chattahoochee and Flint Rivers, and that a scheme for forecasting flood stages could not be based on gage relations, at least without a very extended and time-consuming investigation. This probably results from the fact that the rains over the watershed of these two rivers frequently approach from the west or southwest, covering the lower courses first, and later advance to the upper watershed; although the reverse operation also takes place. In general, then, although the rise in the river may seem continuous at any point, the curve graphically representing the rise is in reality complex, resulting from the combination of two or more curves at different phases. Occasional use is made of gage relations in general, since the limit of a possible rise may be determined for each river gage by the crest stages at the upper stations, and especially between the two lower stations on the Flint-Albany and Bainbridge, and the two lower stations on the Chattahoochee-Eufaula and Alaga. This matter will, however, be made the subject of a separate investigation when time permits. In order, therefore, to complete a practical scheme for forecasting river stages another plan was followed, the principle of which may be described as follows:

It is evident that in every case and under all conditions the stage of a river must be a function of the rainfall over the watershed above the station. That is, for any station a factor may be found which will give the probable rise in the river in feet on the river gage corresponding to an average rainfall of 1 inch over the watershed. But this factor will necessarily be modified by many different causes, some of them of permanent character (which need not be considered) and others of fluctuating character which determine the various different rises due to nearly the same amount of precipitation. These fluctuating factors are, for example, the irregular distribution of rainfall, the rapidity of fall, the previous condition of the ground (or level of the ground waters), temperature conditions, initial stages, effect of water released from power dams, and many others.

The study required the untangling of these different factors in order that each might be given its proper value or weight in the rules for forecasting. Nevertheless the number of rules should be kept to the smallest possible minimum in order not to defeat the aim of the river forecast scheme, to enable the forecast official quickly to determine the probable stage of a river from telegraphed rainfall reports. A too minute dissection of rules would defeat this purpose.

The factor or rise in feet for each inch of precipitation will, of course, be different for each river station. Its value depends primarily on the nature of the bank at the

station. If the possible range of the river is considerable, owing to its narrow channel with steep banks, the factor or rise per inch of rainfall is correspondingly large. For example, at West Point, Ga., on the Chattahoochee, the river rarely exceeds a stage of 20 feet, and the rise for an inch of rainfall during the winter-spring season when the rivers of Georgia undergo the greatest fluctuations is only 4.1 feet; on the other hand at Eufaula, where the river

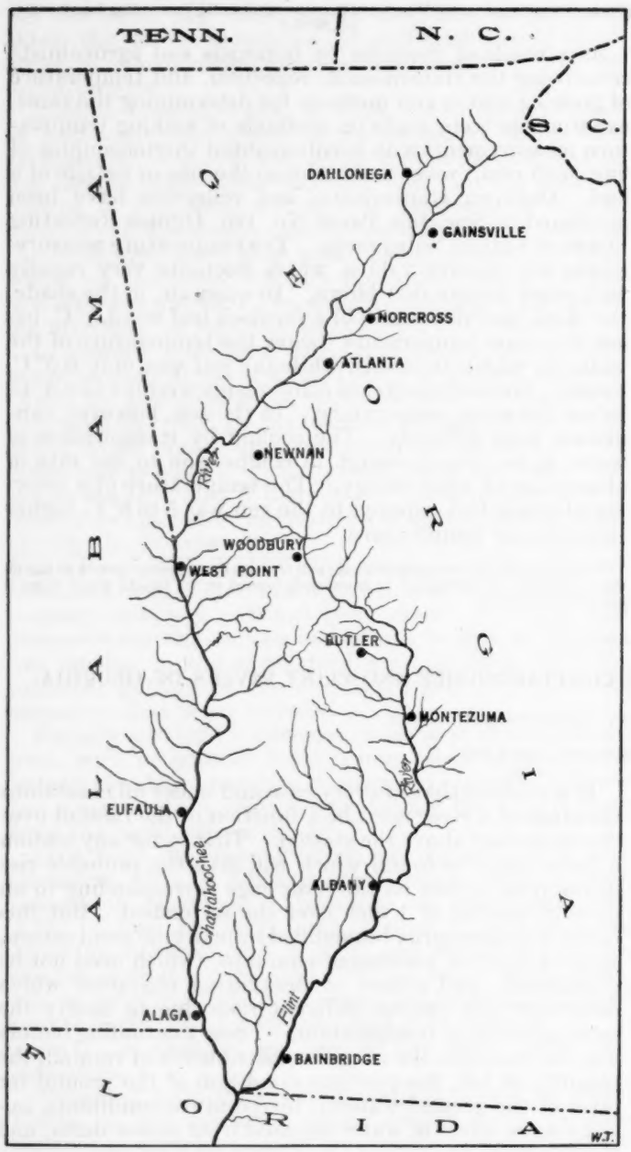


FIG. 1.

ranges as high as 50 feet or more, and often exceeds 40 feet, the rise per inch of rainfall is 10.4 feet.

The average winter-spring factors for the Chattahoochee and Flint Rivers are as follows:

CHATTAHOOCHEE RIVER.	Feet.	FLINT RIVER.	Feet.
Norcross	3.7	Woodbury	2.3
West Point	4.1	Montezuma	4.6
Eufaula, Ala	10.4	Albany	4.7
Alaga, Ala	7.1	Bainbridge	3.8

The summer-fall factors are much less and can not in most cases be accurately determined because of the paucity of high stages during the summer season. The diminution in the factor is no doubt due: (1) To higher temperatures which cause a rapid evaporation of the rainfall besides increasing the capacity of the air for water vapor; (2) the fact that the rainfall is locally distributed in the form of thundershowers, which rarely cover a great area; (3) the cultivated condition of the soil (a fluctuating factor that must be taken into account). There seems to be a sudden rise in the factor early in December in this section.

MODIFYING CONDITIONS.

Taking up the several fluctuating conditions that modify the several factors, it has been found that they cause an increase or diminution in the rate of rise in the river for different stations.

Rule 1. If the weather has been very dry for a month or more, or even for only a few weeks immediately preceding the rise in the river, the factor must be diminished, for the Chattahoochee River, on the average about 45 per cent, and for the Flint River about 25 per cent. This result has not been found to be modified at all by the prevailing temperatures.

Rule 2. General rains during the month immediately preceding the rise, or within even a week or two preceding, require that a marked increase be made in the factors used to compute the rise. This is obviously due to the saturated condition of the soil, or higher ground waters so that much of the rainfall enters the rivers which would otherwise be used to saturate the soil. This factor is distinctly modified by the temperature prevailing at the time. Cold as well as wet weather has a greater effect, while if the average temperature during the preceding wet weather is much above the normal the effect of the rainfall is almost nullified. The winter-spring factor must be increased on the average as much as 50 per cent for the Chattahoochee and 25 per cent for the Flint River. In some cases the effect is further increased by several months of wet weather preceding.

Rule 3. When the precipitation occurs in a relatively brief period of 24 to 36 hours, it enters the rivers more rapidly and the factor must be increased. The increase varies from about 25 per cent for the Chattahoochee to 15 per cent for the Flint. The percentage of increase, however, also varies according to the distribution of the rainfall in the upper, middle, or lower part of the watershed.

Rule 4. Heavy precipitation in the immediate vicinity of the station, in the lower or even in the middle watershed, increases the factor, often enormously, and the failure to predict flood stages in time will result from this cause oftener than from any other. The average increase required for the lower Chattahoochee River is 40 per cent, but on some occasions has required an increase of as much as 75 per cent. It is much less for the Flint River, averaging only 20 per cent.

Heavy rains in the lower or middle portion of the watershed cause a more rapid run-off and diminish the duration of the rise considerably.

Rule 5. On the other hand, if the heaviest rains fall in the upper watershed the factor must be moderately diminished, on the average about 15 per cent for both rivers. The duration of the rise is increased.

Rule 6. With high initial stages the factor must be rapidly diminished. This results of course from the spreading of the water over continually wider areas, and depends

so much on the nature of the river bank at each station there is no uniformity in the percentage of decrease for different stations, but of course it approximates always the same for an individual station. Very heavy rains occurring after the rivers are much above flood stages usually merely lengthen the duration of the flood.

Rule 7. The influence of temperature conditions has already been noted in one or two cases. There seems to be no doubt that lower temperatures increase the effect of heavy rains and higher temperatures diminish it. On the other hand a change in temperature to decidedly colder *after* the rains have fallen, which is the usual course of events in winter and early spring, does not seem to have much effect on the subsequent rise of the rivers in this section, possibly because the Flint and Chattahoochee Valleys are located too far south and the water never freezes. The lower river stations are too near the Gulf.

Rule 8. The duration of the rise at each station varies considerably. The differences in the Chattahoochee and Flint Rivers, whose watersheds are practically in the same geographical region, are very remarkable. The Chattahoochee is a very flashy stream, and the forecaster will hardly have time enough to prepare his forecasts, while the rise of the Flint is gradual; often the crest of the rise has passed Alaga, the most southern station on the Chattahoochee, two or three days before the crest has reached Bainbridge, the most southern river station on the Flint River. On the average the Chattahoochee will require four to five days from the beginning of the rise to the crest stages, and the Flint 6 to 8 or 10 days. The duration is chiefly shortened by heavy rains in lower watershed, previous wet weather, and high initial stages, and is lengthened by heaviest rains occurring in the upper watershed and preceding dry weather.

Rule 9. The average rainfall from telegraphed reports should be computed for all stations from which telegraphic reports are usually received; that is, in making up the average rainfall on any occasion the dividing number should always be the same. Sometimes when the amounts telegraphed are very nearly the same from all stations it becomes more accurate to use the factors based on all rainfall reports received.

Rule 10. The average amount of precipitation required to cause flood stages in both the Flint and Chattahoochee Rivers in the winter-spring season is about 3.25 inches and in the summer-fall season is very much greater, unless, indeed, a long period of very rainy, cool weather has characterized the summer.

THE PROCESS OF ESTABLISHING THE RULES.

1. Since we are not primarily concerned with gage relations, the investigation is made for each river station separately.

The first step was to accumulate all river-gage records on sheets (Form 1078) to avoid constant reference to the river-record books, which would be very time consuming.

2. Tables were then prepared for each river station giving the highest and lowest and mean river stages for each month of the year from all available records, together with the number of times the stages were less than the monthly mean, and the number of times the river was above the flood stage.

3. An investigation of previous flood stages was made, what warnings had been issued, with description of each flood in detail.

4. An investigation was made of the gage relations at the several river stations for flood stages only.

5. For each river station tables were prepared giving:

(*a*) Date of each pronounced rise (usually any rise to a stage half way to the flood stage).

(*b*) The extent of the rise, i. e., initial low stage, highest stage, range, duration of the rise in days, and the mean change per day.

(*c*) Gage heights at upper stations and dates of same.

(*d*) Dates of the rains that caused the rise; amounts of rainfall over the watershed determined from all records of rainfall available, duration of the rains, and then the average factor or rise in feet in the river corresponding to each inch of rainfall.

(*e*) The average precipitation as determined only from the telegraphed reports of rainfall and the corresponding factor. This telegraphic factor will nearly always be higher than the previously mentioned factor.

These tables were recomputed at least three times, for at first it will be found that rains are included at the beginning or close of the several rises which subsequent investigation will show to have had no part in the rise. The average factors for the several months (the data all being arranged by months) were computed after the tables had been revised once, and were not afterwards changed, even though some factors were modified subsequently, provided they worked out well in the rules. Hence the factors used in the Table of Rules for Forecasting River Stages for each station do not always quite correspond with the means from the tables.

6. The mean initial stages, mean duration of the rises, and average daily changes, mean factors, etc., were then computed.

In Table 1 is given an example of the method of studying the relation of rainfall to rise in the rivers.

The rules are not established until every month for which records are available has been tabulated and studied in this way.

If a sufficient number of records is available, it will be found, for example, that in certain cases the rise is what may be called quite normal without complicating factors; in other cases the only modifying factor may be rainfall in the upper watershed; or preceding heavy rains only, or high initial stage, etc. It will be found not difficult gradually to untangle the effects and find a rule for each modifying factor which will be applicable to other cases where even a number of other factors exists at the same time.

Study the computation of the rises for West Point, February, 1917. These rises were computed by the rules which had been established for that river from all records up to but not including 1916, or 1917.

COMPUTATION OF THE RISES FROM THE TELEGRAPHED RAINFALL, WEST POINT, GA., FEBRUARY, 1917.

1. Rise of February 1–3, 1917:

Rains telegraphed Feb. 1:	Inches.
Dahlonega	1.89
Gainesville	1.70
Norcross	1.32
Atlanta up to 7 a. m.	.88
(Divisor 6=)Mean	.96

The modifying factor is that the rainfall was heaviest in the upper watershed, rule 5. The normal February factor which is 4.3 feet should therefore be diminished 25 per cent and becomes 3.2. Rise indicated on account

of the average rainfall amounting to 0.96 is 0.96×3.2 or 3.1 feet. Initial stage 5.3, hence the crest stage indicated is 8.4 feet.

Crest stage actually reached 8.4 feet. (Error none.)

2. Rise of February 17–22, 1917:

Rains telegraphed Feb. 18:	Inches.
West Point	1.28
Atlanta up to 7 a. m.	.80
(Divisor 6=)Mean	.35
Rains telegraphed Feb. 20:	
Dahlonega	1.51
Gainesville	2.05
Norcross	2.08
Atlanta up to 7 a. m.	1.57
Newman	1.88
West Point	1.18
(Divisor 6=)Mean	1.71
Total	2.06

There are no modifying factors for this rise, which is a normal one. The mean February factor for West Point is 4.3 feet. Rise indicated with the total rainfall for the two days is 2.06×4.3 or 8.9 feet. Initial stage 4.5 feet. Crest indicated 13.4 feet.

Actual stage attained 13.5 feet. (Error −0.1 foot.)

3. Rise of February 24–26, 1917:

Rains telegraphed Feb. 24:	Inches.
Dahlonega	1.71
Gainesville	2.10
Norcross	1.30
Atlanta up to 7 a. m.	.83
(Divisor 6=)Mean	1.01

In this case the modifying factors are:

(*a*) Heaviest rainfall in the upper watershed, rule 5, diminish the factor 25 per cent.

(*b*) Heavy rains and high stages just preceding, rule 2, increase the factor 60 per cent.

(*c*) High initial stages, rule 6, decrease the factor 20 per cent.

The normal February factor is 4.3 per cent; diminished 25 per cent becomes 3.2 feet, increased 60 per cent it becomes 5.1; and finally diminished 20 per cent it becomes 4.1.

Rise indicated 1.01×4.1 or 4.1 feet. Initial stage 8.6 feet. Crest indicated 12.7 feet.

Actual stage attained 12.6 feet. (Error +0.01.)

EXAMPLE OF A SET OF RULES FOR RIVER FORECASTING.

Forecasting river stages at Albany, Ga.—Telegraphic reports are available from Atlanta, Newnan, Woodbury, Butler, Montezuma, and Albany. Divisor always 6.

Rule 1. The normal rise in the Flint River at Albany Ga., at different seasons of the year is given in the following table:

Month.	Factor based on—	
	All rainfall records.	Telegraphic reports only.
January	3.6	4.7
February	3.4	5.0
March	3.0	4.0
April	2.9	5.0
December	3.8	4.8
Winter-spring mean	3.3	4.7
Summer-fall mean	2.7	3.4

Rule 2. Flood stages do not occur at Albany with less than an average of 2.65 inches of precipitation over the watershed in winter, and 3.75 in summer.

Rule 3. The crest stage at Albany will normally be reached in 6 days from the beginning of the heavy rains or commencement of the rise, but this time may be diminished 2 days when the rainfall is heaviest in the lower watershed, or the initial stage is high.

Rule 4. For very dry weather during the preceding month or even during the few weeks just preceding the rise, the normal factor must be diminished 30 per cent.

Rule 5. If the preceding month or even only a few weeks have been very wet and cold, the factor should be increased 25 per cent, except that a preceding very wet period with *decidedly high temperatures* has no effect.

Rule 6. When the precipitation occurs practically in 24 to 36 hours with the bulk of it in the lower watershed (below Montezuma) increase the factor 30 per cent. If the bulk of the rain falls in the middle watershed increase the factor only 10 per cent.

Rule 7. When the heaviest precipitation falls in the lower watershed (Montezuma to Albany) then the factor giving the rise per inch of rainfall should be increased 11 per cent. When the heaviest rainfall is in the middle watershed increase the factor only 8 per cent.

Rule 8. When the rainfall is heaviest in the upper watershed, decrease the factor 15 per cent.

Rule 9. With high initial stages diminish the factor as follows: Initial stage above 10 feet diminish it 20 per cent; initial stage about 15 feet diminish it 25 per cent.

Rule 10. The following corrections applied to the stage at Montezuma two days before will indicate the approximate stage at Albany:

	Feet.
0 to 10 feet	−1.0
10 to 15 feet	+2.0
15 to 25 feet	+6.0

EXAMPLES SHOWING THE APPLICATION OF THE ABOVE RULES.

April 25 to May 4, 1908.—The river rose from 8.3 to 27.9 feet.

Date.	River stages (feet).	Rainfall telegraphed (mean).	Date.	River stages (feet).	Rainfall telegraphed (mean).
April 23		0.76	Apr. 29	18.5	
24			30	19.8	
25	8.3	1.14	May 1	23.5	
26	9.3		2	26.8	
27	11.0	2.82	3	[1] 27.9	
28	15.0				

[1] River remained above the flood stage until the 6th.

1. The rainfall of the 23d and 25th all occurred in the upper watershed.

Although April was quite wet it was also extremely warm, the mean temperature for Georgia exceeding the normal by 4.7°; hence no allowance is made for the wet month preceding, in accordance with rule 5.

The normal factor for April is 5; this should be diminished 15 per cent in accordance with rule 8 and becomes 4.2. Indicated rise with the rainfall of the 23d and 25th, 1.90 × 4.2 or 8 feet, which added to the initial stage 8.3 indicates a stage of 16.3 feet by the 29th.

2. The rainfall of the 27th was more general but somewhat heavier in the middle watershed, and the stage at the time the rainfall was telegraphed was 11 feet. Apply rule 9. The normal factor 5 should be diminished 20 per cent, and becomes 4. Indicated rise 2.82 × 4 or 11.3 feet. Computed crest 16.3 + 11.3 or 27.6 feet.

Actual stage attained 27.9. (Error − 0.3 feet.)

March 6 to 22, 1902.—The river rose from 10.9 to 26.2 feet.

Dates.	River stages.	Rainfall telegraphed. (mean).	Dates.	River stages.	Rainfall telegraphed (mean).
	Feet.			*Feet.*	
Mar. 4		0.28	Mar. 14	16.3	
6	10.9	.84	15	16.2	3.32
7	12.3		16	20.0	
8	13.3		17	22.5	
9	14.3		18	22.2	
10	14.5		19	21.7	
11	14.3		20	23.5	
12	14.9	.58	21	25.7	
13	15.8		22	26.2	

1. With the high initial stage of 10 feet reduce the normal factor for March, or 4, by 20 per cent when it becomes 3.2 (rule 9). Indicated rise with the rainfall of the 4th and 6th, 1.12×3.2, or 3.6 feet. Stage indicated by the 10th, or 6 days from the beginning of the rains, 10.9+3.6, or 14.5 feet. Actual stage reached 14.5 feet. (Error none.)

2. The rainfall of the 12th was heaviest near the station, and by rule 7 the factor should be increased 11 per cent and becomes 4.4 which by rule 9 should be diminished 20 per cent since the initial stage is above 10 feet and becomes 3.5. Indicated rise 0.58×3.5, or 2 feet. Stage 14.5 plus 2 feet or 16.5 is indicated by the 14th, or 1 day less than the normal time, because the rainfall was heaviest in the lower watershed. Actual stage reached 16.3 feet. (Error+0.2 feet.)

3. The rainfall of the 15th was heaviest in the upper watershed, but as the initial stage is already above 15 feet so that rule 9 applies, no allowance need be made, except that the crest stage will be delayed 2 days beyond the normal or to the 22d instead of the 20th. In this case the river had begun to fall on the 18th and 19th, when the flood from the upper course began to have its effect on the river at Albany.

Applying rule 9 and reducing the normal March factor 4, by 25 per cent, it becomes 3: rise indicated with the rainfall of the 15th, 3.32×3 or 10 feet. Initial stage (stage on the 15th) 16.2. Indicated crest 16.2+10 feet, or 26.2 feet. Stage actually attained 26.2 feet. (Error none.)

April 17–24, 1912.—The river rose from 6.1 to 30.2 feet.

Date.	River stages.	Rainfall telegraphed (mean).	Date.	River stages.	Rainfall telegraphed (mean).
	Feet.	*Inches.*		*Feet.*	*Inches.*
Apr. 16		0.44	Apr. 21	18.7	2.15
17	6.1	1.68	22	24.3	
18	7.7		23	29.6	.80
19	10.8		24	[1] 30.2	
20	13.0				

[1] Above the flood stage to the 30th.

1. The preceding month was very wet. Hence, by rule 5 the normal factor for April, which is 5, should be increased 25 per cent, and becomes 6.2 feet. Indicated rise with the rainfall of the 16th and 17th, 2.12×6.2, or 13.1 feet. Probable stage in 6 days, or on the 21st, 6.1+13.1, or 19.2 feet. Actual stage reached 18.7 (Error+0.5 feet.)

2. The rainfall of the 21st was heaviest near the station, hence, since March was excessively wet, the factor in addition to receiving the increment indicated by rule 5 as above, should also be increased 11 per cent in accordance with rule 7, and becomes 6.9. But since the initial stage is now above 10 feet, the factor should be diminished 20 per cent in accordance with rule 9, and becomes 5.5. Indicated rise with the rainfall of the 21st 2.15×5.5, or 11.8 feet, which, added to the actual stage attained on the 21st, gives a probable crest stage of 18.7+11.8, or 30.5 feet. The crest will be reached in 4 days (6−2) because the rainfall was heaviest near the station. Actual stage attained 30.2. (Error+0.3 feet.)

3. The rainfall of the 23d caused no further rise but served to maintain flood stages to the 30th.

March 13–21, 1913.—The river rose from 6.5 to 30.3 feet.

Dates.	River stages.	Rains telegraphed (mean).	Dates.	River stages.	Rains telegraphed (mean).
	Feet.	*Inches.*		*Feet.*	*Inches.*
Mar. 13	6.5	1.66	Mar. 18	26.3	
14	8.0	1.28	19	28.1	
15	13.0	2.25	20	30.0	
16	21.1	.50	21	30.3	
17	25.2				

1. February and March were very wet. Use the normal factor for March, which is 4, increased 25 per cent in accordance with rule 5, making it 5 feet. Indicated rise with the rainfall of the 13th and 14th 2.94×5, or 14.7 feet. Initial stage 6.5; stage indicated by the 17th, 21.2 feet.

2. But the heavy rains of the 14–15 (telegraphed morning of the 15th) rapidly entered the river, being heaviest in the vicinity of the station (Albany 4 inches). Applying rule 7, the March factor becomes 4.4, but as the stage was now above 10 feet, this is reduced to 3.5 by rule 9. Indicated rise with the rainfall of the 15th, 2.25×3.5, or 8.8 feet, which, added to the computed stage on the 21st, gives a probable stage about the 20th of 30 feet. (Error none.)

3. The small amount of the precipitation telegraphed on the 15th, when the stage was above 20 feet, would not have justified predicting higher stages, as at stages above the flood stage, which is 20 feet, the factor at once diminishes enormously, at Albany at least 80 per cent. So that the only further rise that could have been expected would have been 0.50×0.8, or 0.4 foot, to a crest of 30.4 feet. Actual stage reached 30.3. (Error+0.1 feet.)

These few examples will serve to indicate the practical application of the rules.

TABLE 1.—*Daily precipitation for February, 1917.*

Stations.	Watersheds.	Day of month.																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Dahlonega, Ga	Chattahoochee	1.89			T.	0.05			0.04	0.02						0.64	T.	0.68	0.83	1.51	0.14			T.	1.71		T.		
Gainesville, Ga	do	1.70				.10						0.05				.80			.85	.98	2.05	.25			2.10				
Norcross, Ga	do	1.32		0.01		.04			.01	.04	0.02		0.04		0.60				.82	.46	2.08	.26			1.30				
Canton, Ga	do	1.89		T.		T.			T.	T.	T.	T.	T.			.81			.59		1.60	2.50	T.	T.	2.06				
Lost Mountain, Ga	do	0.98				.05										.14			.68	1.00				1.55					
Atlanta, Ga	do	0.88	T.	T.		.10			T.	.13	T.	T.	.01		T.	.51		T.	.80	.86	1.57	.17		T.	.83				
Newnan, Ga	do	0.70	T.		T.					.03						.04			.75	.45	1.88	.34		T.	.33	T.			.06
West Point, Ga	do	0.62				.01			.11	.08			.10			.25			1.28	.29	1.18	.03		.02	.19				.02
Mean		1.25	T.	T.	T.	.04			.02	.04	T.	.01	.02		T.	.47	T.	T.	.81	.81	1.60	.14		.20	1.06	T.	T.		.01
River stages (feet) at West Point.		5.3	7.3	8.4	7.3	5.4	5.0	4.7	4.7	4.7	4.5	4.7	4.3	4.0	4.3	4.3	4.5	4.5	5.0	5.9	9.7	12.7	13.5	13.2	8.6	9.8	12.6	10.8	6.2

Example No. 1.—Feb. 1–3, 1917, rise 3.1 feet, rainfall 1.2 inch, factor 2.5 feet for each inch of rain. Modifying conditions: Heaviest rainfall in upper watershed.
Example No. 2.—Feb. 17–22, 1917, rise 9.0 feet, rainfall 3.36 inches, factor 2.7 feet.
Example No. 3.—Feb. 24–26, 1917, rise 4.0 feet, rainfall 1.26 inch, factor 3.2 feet. Modifying conditions: Rainfall in upper watershed, preceding heavy rains, high initial stages.

135313—19——3

WEATHER IN CINCINNATI, OHIO, FOR 130 YEARS.

By W. C. DEVEREAUX, Meteorologist.

[Dated Weather Bureau, Cincinnati, Ohio.]

The first permanent settlement in the State of Ohio was made at Marietta in the spring of 1788, and during the fall of the same year three settlements were started at and in the vicinity of what is now the city of Cincinnati. These settlements were first called Columbia, Losantiville and North (or Great) Bend. The name Losantiville was changed to Cincinnati by Gov. St. Clair on January 1, 1790; Columbia was annexed to Cincinnati several years later; and North Bend is a separate town a few miles below the city.

In the year 1815, Dr. Daniel Drake published his book entitled a "Picture of Cincinnati," and nearly one half of this excellent volume of 251 pages is devoted to "Observations on the weather, the earthquakes, the aurora borealis and the southwest wind."

The daily observations summarized in Drake's book cover a period of eight years from 1806 to 1813, inclusive, and occasional observations are given for the period from 1789 to 1805. The thermometers used were "made in London and known to be correct by being subjected to the proper experimental examination." They were hung in contact with wood on the north side of the house, under shelter, and read before sunrise and at or a little after 2 p. m.

Up to 1815 the greatest degree of cold ever observed at this place was 18° below zero on January 8, 1797, as recorded in the manuscript of Gov. Sargent. During eight years the thermometer fell below zero on an average of two times each year and rose to 90° or higher fourteen times each year. The average annual temperature was 54° and the annual rainfall was about 36 inches, although "the amount had not been accurately determined." That these figures are unusually reliable is shown by comparison with 48 years record by the Weather Bureau ending with the year 1918, when the average temperature was found to be 55° and the rainfall 38 inches. In this connection it is interesting to note that Drake said in 1815, when Cincinnati was about 25 years old, "that our climate has undergone a change is the opinion of many people."

Drake states the the amount of snow which fell each winter averaged about 18 inches, and the usual fall for each storm was not more than 4 inches, except in one storm when about 10 inches fell. The ground seldom remained covered with snow longer than two or three days. Frosts, probably light, were reported as late as the first week in May, and the earliest frost in the fall occurred during the last week in September, but on the last day of August in 1789, "the Indian corn in the northern part of Kentucky was killed by frost." The Ohio River at Cincinnati was "blocked up" with ice every fifth year on an average. The new town was flooded in 1793 and again in December, 1808.

Drake found from six years observation that the wind at Cincinnati was southwest about 30 per cent of the time, and that all the severe winds were from the southwest or northwest. The most destructive windstorm was that of May 28, 1809, when several buildings were demolished, and "the tornado ascended the hill to the northeast of the town, forming a track through the forest, which remained visible more than a year," but the inhabitants escaped injury. On the 20th of April, 1814, "a tornado laid waste a strip of country between this town and Chillicothe, and another of great violence was experienced 60 miles south in the State of Kentucky." A brilliant aurora borealis occurred on Sunday, April 17, 1814, and according to the description by Drake, it was quite similar to the one observed at Cincinnati, on March 7, 1918. Another one, but less brilliant, occurred on September 11, 1814, and Drake states that these two are perhaps the only unequivocal instances of the aurora borealis observed in the Miami country since its settlement and up to 1814.

According to Drake's records, earthquakes were very frequent for the two years beginning in December, 1811; there were distinct shocks on 27 days in 1812 and some of these were quite severe. As far as known this record of earthquake intensity has never been equaled during any other year in the past 130 years.

Unfortunately the detailed weather records for the period from 1814 to 1834 have not been preserved, if any were kept. The newspapers and other publications of the time gave only casual mention of the weather, and did not publish, as far as known, complete weather data. A record of the temperature for that period was made at College Hill, which is now a suburb of Cincinnati; and the mean annual temperatures were later published in Smithsonian Contributions to Knowledge. These temperatures are shown in the accompanying table and the record is continued until 1848 for comparative purposes. It will be seen that the temperature at College Hill averaged 1.5° lower than that for the lower sections of the city. The maximum and minimum temperatures each year are not available for College Hill, but the highest and lowest temperatures for Marietta, Ohio, for the period of 1818 to 1834 are published in Hildreth's Pioneer History, and these are given in the table. These give a rough estimate of the extreme temperatures at Cincinnati, as the difference in the temperature between the two places seldom exceeds 5° and is usually not more than 2° or 3°.

From miscellaneous sources it is learned that the weather between 1814 and 1834 was of about the ordinary type, with the following exceptions: The months of February and March in 1815 were unusually mild with heavy rains in March, which were followed by a flood in April. The year 1816 was remarkably dry and cold, but the following year was prolific in both heavy rains and high waters. The months of February, 1818, and January, 1821, are described as very cold. Very heavy rains set in in December, 1827, which resulted in a flood in January, 1828, when the river reached a crest stage of 58 feet, probably on the 11th. The rains continued generally heavy during the first half of 1828. The winter months of 1831 were extremely cold and the average temperature for the whole year is the lowest on record, the average at College Hill being 48°, which is 2.4° lower than the record made in 1917, at the Abbe Meteorological Observatory in Clifton, a short distance from College Hill. December, 1831, was described as the coldest December "within the memory of the oldest inhabitants," and it was probably the coldest one since Cincinnati was founded, with the possible exception of December, 1917. At Portsmouth, Ohio, the average temperature for December, 1831, was 22.9°, or 2.7° lower than for the same month 1917, and the temperature at Portsmouth averages about 1° higher in December than at Cincinnati. The "great freshet" of 1832 was preceded by a long spell of unusually severe winter weather with heavy snow, broken by a thaw late

in January. The river reached a crest stage of 64.2 feet on February 19, and this was the highest stage which had occurred during the past 40 years.

Complete weather observations were begun in 1835, in the lower portion of the city, by Dr. Joseph Ray, then professor of mathematics at Woodward College, afterwards Woodward High School. These observations were continued at the same location by Dr. Ray with the assistance of a few others until 1855, when the work was turned over to Prof. Harper. The daily observations for 1837 were published in the Western Academican and the monthly summaries for the period from 1835 to 1850 were published in "Cincinnati in 1851" by Charles Cist. In a special article on "Meteorology" by Dr. Ray, in Cist's "Cincinnati in 1841", the general weather conditions are summarized as follows: "The climate of Cincinnati and vicinity is such as might be expected in its appropriate latitude. It differs from the same parallel at the Atlantic only in being rather more variable in the range of the thermometer, and in the greater frequency of rain in the winter months. Indeed, a fall of many degrees in the thermometer in the course of but a few hours is not uncommon in this city at any period of the year. The cold weather in winter is of intensity equal to that of the east, and perhaps the north, but severe frosts are less frequent in their occurrence, and of briefer existence. Snow rarely lies long enough to furnish sleighing, and the constant alternation of freezing and thawing renders the traveling through unpaved streets in the winter season very unpleasant."

In Februray, 1835, the temperature was 17° below zero and that record was not equalled again until February, 1899. March, 1836, was very cold with temperautre 4° below zero, which exceeds by 5° all low records for March. In April, 1837, 6 inches of snow fell on the 4th and the hilltops were again covered with snow on the 23d. A period of eight very wet years began in 1843 with a total precipitation of 51.25 inches, reached a maximum of 65.18 inches in 1847, and ended with 54.76 inches in 1850. The amount for June, 1845, was 11.50 inches and has been exceeded only once in any month, and the annual amount for 1847 is much the largest on record. The precipitation during this year was so large that the question has been considered as to whether Dr. Ray's rain gage was of standard type and properly exposed, and possibly some allowance must be made for the methods used in securing the records; however, 1847 must have been a very wet year as the river was high, reaching a crest stage of 63.6 feet, and there was 20.6 inches of snow in December. The daily papers in January, 1848, mentioned the fine "old fashioned" sleighing which was being enjoyed at that time, but the same paper a few days later stated that the sleighing had been ruined by a warm rain. There was 10.33 inches of rain and snow in December that year. The snowfall during the winter of 1849–50 reached the remarkable total of 50 inches, which exceeds by 10 inches the amount for any other year.

In the year 1855 Prof. Geo. W. Harper took over the work of making the weather observations and continued the same until 1902. The instruments remained at the Woodward High School until August, 1859, when they were moved to Prof. Harper's residence on Gilbert Avenue, Walnut Hills, near the northwest corner of Eden Park. These records were made for the Smithsonian Institution and only abstracts were retained by Prof. Harper, consisting of monthly data for temperature, pressure, wind direction, and weather, daily data for rainfall and snowfall, and meteorological notes, all of which have recently been turned over to the Weather Bureau. Precipitation records were kept also by R. C. and J. H. Phillipps and F. W. Hurtt from 1855 to 1870, and the monthly and annual amounts have been taken from the Smithsonian publications.

The winter of 1855–56 was the "longest and most severe within the memory of the oldest inhabitants." Near zero weather prevailed for about two months, the lowest being 2° below in December, 14° below in January, with 21° below to the north of the city, and 13° below in February. The Miami River at Hamilton, Ohio, was frozen over on November 4 and remained so until the night of February 22, and the Ohio at Cincinnati was frozen over from January 15 to February 2, it being an "everyday sight to see four-horse teams" crossing on the ice. The following winter was also cold, but the months of December, 1857, and January, 1858, were warm, the lowest temperature in December being 25° and the lowest in January 28°, while the mean for January, 42.5°, is the highest on record for that month. Heavy rains fell the following month, causing a flood of 55.3 feet on February 23. On May 21, 1860, a severe "hurricane" passed over the city, destroying thousands of dollars' worth of property and several lives. It lasted for over a half hour.

In the spring of 1861, frost and ice formed as late as May 2, and there were severe thunderstorms with heavy falls of hail on May 27, June 21, and July 1 and 12, followed, on August 21, by an extraordinary rainfall of 3.35 inches in two hours. In 1862 there was a violent windstorm on February 19, a destructive tornado on May 21 "before day," several severe thunderstorms during the summer months, a bright aurora borealis, and a great range in temperature in October, the highest being 91° on the 8th and the lowest 27° on the 26th.

In the "great snowstorm" of January 15, 1863, 20 inches of snow fell in about 24 hours, and during the "cold New Year's" in 1864 the temperature averaged 10° below zero for the day. February was also cold in 1864, with 5° below zero, and a heavy snowstorm occurred that year on May 11, the snowfall being 1 inch and the temperature 33°. Heavy snow fell in December, 1864, and there was deep snow on the ground during January and the first part of February, and heavy rains fell in March and again in July, causing a high river until the middle of August, with flood stages of 56.2 feet on March 8 and 51.2 feet on May 14. In 1866 there was a light frost as late as May 14, and the whole summer was very cool and wet. The rainfall for September that year was 10.88 inches, which is the third largest monthly amount on record, and for the three months of June, July, and August, the total amount was 26.24 inches, which exceeds all other periods of three months since the records began in 1835.

During the night of June 18–19, 1868, there was an excessive rainfall of 4.50 inches. A moderately heavy snowstorm occurred on October 19, 1869. In 1870 the river reached a crest stage of 55.2 feet on January 19; on June 29 there was an excessive rainfall of 2 inches in 30 minutes; and the months of August and September were very dry.

In 1868, Mr. Frank A. Armstrong, manager of the Western Union Telegraph Co., began the issue of a crude "weather report," showing the weather at about a dozen places. Early in 1869 Prof. Cleveland Abbe, Director of the Astronomical Observatory at Cincinnati, became an interested observer of these maps, and with the assistance of the chamber of commerce, he began the preparation of complete weather maps in the fall of that year. These maps contained reports from about twenty stations to-

gether with a summary of the general weather conditions and local forecasts, and were continued until Prof. Abbe was called to Washington to take charge of the forecast work in the Weather Bureau, which was established as a part of the Signal Corps of the Army, in 1870.

The Weather Bureau opened an office in the old Pike's Opera House, at the corner of Fourth and Vine Streets, on October 12, 1870. Observations were made at that point until March 1, 1885, when the office was moved to the Federal Building at the corner of Fifth and Walnut Streets, where the observations have been continued to date. Prof. Harper continued his observations on Walnut Hills for several years, and the highest and lowest temperatures are given in the table each year from 1871 to 1884 for both Walnut Hills and the lower section of the city to show the variation between the two points. The maximum temperature was highest in some years on the hilltops and other years in the valley, but the minimum temperature was nearly always lowest on the hilltops, the greatest difference being 10° in 1884, when 20° below was recorded on Walnut Hills and only 10° below at the Government building.

In 1871, a heavy frost on April 23 injured fruit trees and a light frost occurred on May 10. The summer of 1874 was extremely warm; the maximum temperature of 103° in July has been exceeded only twice in Cincinnati during the past 91 years, and the average temperature for June, 79.8°, has never been exceeded. The winter of 1874–75 was very severe, and the river was twice blocked by ice and once frozen over. By the middle of February over 5,000 families were deprived of water due to the bursting of many leading water mains by freezing. The month of March, 1875, was remarkable for the great and frequent changes in temperature, and the frequent snows, rains, and thunderstorms. A violent sleet storm occurred on March 3 between 1 a. m. and 8:30 a. m. and four days later, on the 7th, 6 inches of snow fell during the afternoon. On the last day of that year the temperature rose to 72°.

The following year, 1876 (Centennial year), was as remarkable in its weather as in other ways. The year opened with warm, pleasant weather, followed by heavy rains in January; very changeable weather during the spring months; hot, oppressive weather during the summer with an unprecedented hot spell of three days in July; frequent thunderstorms in August, and extremely cold weather in December, when the Miami Canal and ponds froze over on the 2d, the temperature fell to 6° below zero on the 9th, the Ohio gorged on the 10th, with people crossing on the ice by the 19th and heavy loads crossing in safety during the last week of the year. The ice finally went out on January 14, 1877, at a river stage of 32 feet, involving great loss to the river interests.

There was a heavy frost on May 2, 1877, and a very light frost was observed September 19 the same year. The winter of 1878–79 was very cold with temperatures from 1° to 5° below zero in December and from 10° to 16° below in January. The river was gorged with ice from December 25 to January 13 and nearly full of floating ice until February 22, and the snowfall was heavy for the winter with a fall of 4 inches on February 17. The rainfall for August in 1879, 11.72 inches, is the greatest amount ever measured in one month at Cincinnati, and the total amount for 1880, 54.67 inches, is the largest annual amount since 1847. On the 14th of June, 1880, a terrific storm occurred when 2.30 inches of rain fell in two and one-half hours. The following November was the coldest on record. The temperature on the morning of the 19th was 5° above zero at the Federal Building, where a dense fog prevailed, but on the hilltops, where the weather was clear, it was 12° below zero, and on the 27th the canal was frozen to a depth of 5 inches.

The period of three months, beginning with July and ending with September in 1881, is the longest period of intense heat on record for this city. In July the temperature was above 100° on four consecutive days, the maximum of 103.5° and the mean of 81.6° have been exceeded only once in the past 91 years, and the means for August and September have never been exceeded in the corresponding months. In 1882 the river reached a crest stage of 58.6 feet on February 21, which was the highest since 1849; snow fell on April 10, and three light frosts occurred in May, the last on the 23d.

Beginning with August, 1879, and ending with May, 1884, was a period of nearly five years of great rains. The annual amount each year was from 10 to 16 inches above the normal, and during that time 5 of the 12 months recorded the greatest amount on record, for the respective months. These years of great rains culminated in the great floods of 1883 and 1884. In the flood of 1883 the river reached a crest stage of 66.3 feet on February 15, which was the highest stage ever known up to that time, but this record did not stand long, as one year later, lacking one day, viz February 14, 1884, the river reached the extreme stage of 71.1 feet, which has never been exceeded. The last flood was preceded by heavy snows in December and January. In December 10 inches of snow fell between noon of the 22d and noon of the 23d and the snowfall for the month amounted to 17.5 inches followed by 9.8 inches of snow in January. On January 5 the temperature at the Federal Building was 10° below zero, while Prof. Harper's thermometer on Walnut Hills registered 20° below—the lowest on record for this city. Moderately heavy ice formed in the river, but the river did not freeze over, due to the comparatively high stage and to the fact that the weather during January was not extremely cold except from the 4th to the 7th. The extreme high water in February was due to the heavy rains, melting snow, and high temperature during the first half of that month. The rainfall at Cincinnati from February 4 to 13 was 6.82 inches, and this amount has seldom been exceeded during a whole winter month, and the temperature during that time varied between 40° and 67°. The temperature fell to 20° on the 14th, and the flood and cold weather caused intense and widespread suffering, besides the enormous property loss.

For several years following the "great flood" the weather was nearly normal, with mild winters and moderately warm summers and generally free from severe storms. The winter of 1892–93 was unusually cold, and the river was frozen or full of floating ice during the entire month of January. In 1895 the temperature fell to 12° below zero on February 12, and rose to 84° on March 29, both being near the extreme records for the months.

The year of 1897 was characterized by heavy rains and high water. On February 26 the river reached a crest stage of 61.2 feet. A few days later an excessive rain of 4.97 inches fell in about 16 hours, on March 4–5, and this amount has never been exceeded at Cincinnati for the same length of time, and the total amount for that month, 9.89 inches, has never been exceeded in February, March or April. Following this excessive rain on March 4–5, the river rose rapidly again but just reached the flood stage of 50 feet. On May 2, 1.5 inches of snow fell. The rains were especially heavy also in the months

of July and November, 1897, and continued heavy during the first three months of 1898, resulting in another flood with a crest stage of 61.4 feet on March 29.

The year of 1899 was one of extremes in temperature; the lowest in February, −17°, is the lowest ever recorded by the Weather Bureau for any day, and the highest for September, 99°, is the highest on record for that month. The average temperature for the week of February 8 to 14 was zero, and the minimum temperatures were as follows: −1° on the 8th, −17° on the 9th, −12° on the 10th, −3° on the 11th, −6° on the 12th, −11° on the 13th and 0° on the 14tn. The temperature was below zero for fifty consecutive hours and the highest during the five days was 8° above zero. There was considerable ice in the river during February, but no gorge formed. On March 8 the river reached a crest stage of 57.4 feet. During the following summer the temperature was above 90° on 32 days during June, July, August and September and the year ended with a temperature of 2° above zero on December 31.

The year 1900 passed without unusual features, but the year 1901 was very hot and exceedingly dry, especially from August to November. In April the river reached a crest stage of 59.7 feet on the 27th, but this flood was due to heavy rains above, as the amount for April at Cincinnati was less than 2 inches, and the total rainfall for the year was only 17.99 inches, which is considerably less than in any other year. July, 1901, was the warmest month on record, and neither the extreme of 105.2° on the 22d, nor the mean for the month, of 82.4°, has been exceeded in any month. During this month the temperature was 100°, or higher, on four days, and above 90° on 23 days. December of that year was almost as cold as July was warm, and the minimum of 7° below zero on December 15 had been exceeded only once in December, previous to 1917.

An extraordinarily heavy and excessive downpour of rain occurred near noon of May 20, 1902, when 2.28 inches feel in 30 minutes, which exceeds by 60 per cent the next heaviest rain for the same length of time made by an automatic recording gage.

The years from 1903 to 1906 were nearly normal. Heavy rains in January, 1907, caused a flood of 65.2 feet on the 21st of that month, and on March 12–13 of the same year 5.85 inches of rain fell in 31 hours, the greatest amount within 24 hours being 5.22 inches. This amount has never been exceeded for 24 hours, but the rate for 16 hours was exceeded in the storm of March 4–5, 1897, and the rate for 30 minutes was exceeded on July 7, 1912. In the second large flood of 1907, the river reached a crest of 62.1 feet on March 18.

The summer of 1908 was very warm with 42 days on which the temperature was above 90°, but no extreme high temperatures were recorded, and the rainfall of 0.62 inches between August 18 and November 9 is the smallest on record for such a long period. Heavy snow fell during the night of December 24, 1909, and this was followed by several more heavy falls during January and February, 1910, the amount being greatest on February 17, when 10.8 inches fell in 24 hours. The snowfall for that winter was 40.4 inches, which is the greatest amount recorded since 1850. On October 5 and 6, 1910, 4.30 inches of rain fell within 24 hours. The year 1911 was mild during the winter months and warm during spring and summer with frequent thunderstorms. This is the only year on record when the temperature did not fall below 10°, and it was below 20° on only 9 days during the entire year. The first month of the following year was quite the opposite, when for a period of 13 days from January 4 to the 16 inclusive, the temperature averaged 10° and the lowest was 9° below zero. February was also cold with temperature 7° below zero. There were several severe thunderstorms during the summer of 1912, the more destructive ones occurring on May 5, June 16 and 21, July 17 and August 28.

The year 1913 was characterized by high temperatures, excessive rainfall, two great floods, and an unprecedented rapid rise in the river during the first half of the year. The months of January and March were especially warm and a maximum temperature of 76.7° on the 14th of the latter month was the highest ever recorded between January 1 and March 15. Rains were unusually heavy in January and March with total amounts of 9.02 and 9.09 inches, respectively. The flood of January was more than ordinarily high, reacning a crest of 62.2 feet on the 14th, and then followed the great flood in the latter part of March, when the river reached a crest of 70 feet on April 1. While this flood was 1.1 feet lower at Cincinnati than the flood of 1884, due to the absence of secondary rises in the local tributaries just before the crest was reached, still in all other respects the flood of 1913 was the greatest ever known in the Ohio Valley. The rise of 21 feet in 24 hours in the river has never been exceeded at Cincinnati.

The unusual features of the year 1914 were the heavy snowfall of 21.4 inches in February, which has been exceeded only by the 23.5 inches in January, 1863; and the hot, dry summer, with a record temperature of 100° for June, followed by 103° for July. The summer of 1915 was generally cool and wet, both the average temperature for August, 68.6°, and the lowest, 43.1°, being the lowest on record for that month. On July 7 a very destructive storm passed over the city, when the wind reached an extreme velocity of 62 miles per hour, accompanied by a torrential rainfall. This storm approached the city from west-southwest, and struck the business section of the city at 9:29 p. m. and during the next minute the wind blew at the rate of 62 miles per hour and rain fell at the rate of 6.24 inches per hour, resulting in the loss of about 40 lives and more than a million dollars worth of property.

The year 1916 averaged nearly normal in both temperature and precipitation, but the weather was quite changeable during the entire year, with both unseasonably warm and cold days during the winter months, and a very cool June followed by hot dry weather in July and most of August. The weather continued nearly normal during the entire winter of 1916–17, except for five days early in February, when the temperature was below zero each day, the lowest being 9° below on the 5th. On March 11, 1917, a well-defined and destructive tornado developed over the eastern portion of the city, and moved slightly north of east across the southern portion of Hyde Park, the path of greatest destruction being about three-fourths of a mile long and varying from 50 feet to 300 feet in width. Fortunately, only three people were killed but 90 houses were totally or partially destroyed and the property loss was large. During the night of September 7–8, 1917, an excessive rain fell which was very heavy at Fernbank Dam, in the lower portion of the city. At that place 5.83 inches was measured in the Government gage, all of which fell in 11 hours. This considerably exceeds the record of 5.22 inches within 24 hours in March, 1907, and the fall of 4.97 inches within 16 hours in March, 1897. The summer and fall of 1917 were cool with mean temperatures below the normal every month and the means for May and October were the lowest on record for these months. The cold increased in intensity as the season advanced

and reached the maximum intensity in the severe cold winter of 1917–18, which exceeded all previous records for length of cold period and for extremes in December and January. The severe cold weather began on December 7, 1917, and continued with very little interruption until February 6, 1918. During this period the temperature was below zero on 17 days and near zero on several other days. The mean temperature for December, 22.3°; the minimum for December, −13°; the mean for January, 16.3°; and the minimum for January, −16°, were all considerably below previous records. The snowfall during this winter was very heavy, with a fall of 12 inches on December 8, a total fall of 36.5 inches during December and January, and an average depth on the ground of 13.5 inches on January 22. Great ice gorges formed in the river during the cold weather, which caused two great backwater floods with crest stages of 61.2 feet on February 1 and 61.8 feet on February 12, on which latter date the great gorge at Sugar Creek Bend finally broke. Nothing on record for December compares with the cold December of 1917. During that month the temperature was below zero on 9 days while for the preceding 50 years it had been below zero for a total of only 17 days, the greatest number in any one year being 4 days in 1901 with a minimum of −7°. December of 1831 may have been about as cold as December, 1917, but we do not have sufficient data to make a reliable comparison.

In January, 1918, the minimum temperature was not much lower than had been recorded in January during other years and not even as low as the −18° reported on January 8, 1797, but the average for the month in 1918 was 16.0° below the normal and 5° below the average for the cold Januarys of 1893 and 1857. On the whole the winter of 1917–18 was the longest and coldest on record, although the cold was not quite so intense during any week as it was during the cold week of February, 1899. The early spring months of 1918 were generally warm followed by a very cool July with a record low temperature of 51° on the 22d, followed in turn by a record high temperature in August of 102° at the Federal Building and then a change to the coolest September on record. The winter of 1918–19 in contrast with the preceding one generally, was mild and pleasant with only 1.6 inches of snow.

THE ABBE METEOROLOGICAL OBSERVATORY.

Since April 1, 1915, the Weather Bureau has been making complete records at both the Federal Building in the lower portion of the city and at the Abbe Meteorological Observatory, on Lafayette Circle, Clifton, on the hilltops, and the records at both locations are given in the table for comparative purposes. On an average the temperature is 2.0° lower, and the maximum and minimum each day from 1° to 4° lower at the Observatory than at the Federal Building. Under the most favorable conditions during a cold period when the wind is very light and fog or local smoke fills the valley, the temperature will fall 6°, 7° or even 8° lower at the Observatory than at the Federal Building, and during a warm day with bright sunshine and very little wind the temperature will occasionally be 6° or 8° higher at the Federal Building than at the Observatory, but these extreme variations seldom happen. The wind direction and velocity vary considerably at the two locations due partly to the topography of the region and partly to the exposure of the wind instruments.

The precipitation thus far has averaged nearly the same at the two locations. As will be seen by the table the precipitation for 1916 was 3.58 inches more at the Observatory than at the Federal Building, but during the two following years the amounts were somewhat larger at the Federal Building. On several days during the past three years more rain has fallen at one location than at the other but the difference is partly compensated by the end of the month and nearly disappears by the end of the year.

AVERAGE WEATHER CONDITIONS.

The weather conditions mentioned in the above notes are principally the abnormal features and severe storms during the past 130 years. The following is a brief description of the usual weather of Cincinnati, year after year.

Winter on the average begins about the 15th of December and lasts until the 15th of March. During the first half of December the minimum temperature is frequently below freezing but the maximum temperature rises to about 45°. About the 15th of that month the first cold spell usually occurs and there are, occasionally, fairly good snow storms. The first cold spell lasts only two or three days and the temperatures are more moderate again with very little snow between December 20 and Christmas, but the temperature falls more rapidly during the last week of December and continues to fall slowly during January. The wind is seldom strong enough in Cincinnati to be troublesome at any time during the year, and is generally sufficient to produce a gentle movement of the atmosphere and prevent the formation of stagnant pockets of very hot or very cold air; however, there is a moderate increase in wind velocity during the winter from 7.7 miles per hour in the middle of December to 8.7 miles at the end of February. The precipitation does not change much in amount during the winter months, averaging about 0.11 or 0.12 inch a day, or near 3.50 inches a month, with a slightly larger amount during the first three weeks of February. The winter rains sometimes are moderately heavy and continue for two or three days or longer, but very seldom are excessive for a short period of time, there having been only five winter (December, January, and February) storms during the last 20 years, when the rainfall was excessive. In March the rains are more frequently excessive than during the preceding three months and the greatest amount on record for 24 hours, 5.22 inches, fell on March 12–13, 1907. When the precipitation is in the form of snow, most of it falls in January and February with a slight tendency to a maximum about the second week of January; however, the snow seldom remains on the ground more than a few days before it is melted by a rise in temperature, or rain. Thunderstorms are almost unknown during the last half of December and the first half of January, but do occur occasionally late in January and more frequently in February. Although the temperature falls slowly during January, there is frequently a mild period about the third week of that month, followed by falling temperature again late in the month, and the coldest part of the year is the first few days in February, when the average daily minimum reaches the lowest point, 18.5°, on February 2, and the average daily maximum the lowest point, 34.2°, on the 5th. After the first week in February the average temperature rises steadily and rapidly, the rise in the first two weeks being as great as the fall during the preceding six weeks, and by the end of February the winter is frequently over, except for an occasional cold, stormy day during the first half of March.

Spring weather on the average begins about the 15th of March and continues until the middle of June. The average minimum temperature at the beginning of spring

is very near the freezing point and in many years it will not fall to that point again, although killing frosts quite frequently occur in April, the average date of the last killing frost being April 14. The temperature rise during the latter part of March and during April is the most rapid for the year, and by the end of April it ranges from 47° to 68°, and by the 15th of June from 62° to 82°. The amount of precipitation during the spring continues about the same as during the winter, although there is a slight increase in the last half of March and a slight decrease in April. Thunderstorms occasionally occur in April, but very seldom is the rain excessive. However, in May the thunderstorms occur quite frequently and excessive rains fall on an average of one each May. There is a decided increase in rainfall late in May and the first half of June, the average amount on the 12th of June being 0.16 inch, the largest of any day in the year. The wind velocity continues moderately strong during March, but begins to decrease late in that month and decreases quite rapidly through April and May, the average velocity in June being only 6 miles per hour.

Summer weather usually begins about the middle of June and continues to the middle of September. The maximum temperature averages above 80° during the entire summer, the highest being 86.7° on July 15, and at this time the minimum temperature averages 66°. Temperatures above 90° frequently occur in July and August, and occasionally the temperature goes above 100°, but the periods of extreme heat are usually short, lasting from three to five days. June has a slightly greater rainfall than any other month, the average being 3.82 inches, while the remaining months of the summer have about 3.4 inches each. Thunderstorms are quite frequent in June, with an average of 7 and also averaging 6 in each of the months of July and August. Excessive rains are most frequent in August, although the number does not greatly exceed that for May, June, or July, and a large proportion of the excessive rains of the year occur in these four months. Droughts are not of frequent occurrence, but when one does come it generally begins late in July or in August and continues into September or October. Dense fogs very seldom occur in the summer, only two having been recorded in July in the past 36 years and very few in the other summer months. The average wind velocity continues below 6 miles per hour all summer, with occasional high winds attending thundersqualls, and the direction is variable as during the other seasons of the year.

Fall may be said to extend from the middle of September to the middle of December. During this season there is an unsteady though general decrease in the temperature, a rapid decrease in the number of thunderstorms, and a gradual decrease in the rainfall until the middle of October, followed by a sharp increase in November. The average daily rainfall in the middle of October is only 0.05 inch, or one-third of the average for the middle of June, but by the third week in November the average has increased to 0.14 inch. Fogs are more numerous during October than any other month in the year, but severe storms seldom occur in the fall. Light frosts occasionally form in September and the average date of the first killing frost is October 25. The minimum temperature averages below freezing after November 23, but the weather usually contiunes mild until the middle of December. On the whole, fall is the most pleasant season of the year in Cincinnati.

Tables of comparative weather data for Cincinnati, Ohio.

Observers.	Place of observation.	Year.	Temperature. Mean.	Maximum.	Date.	Minimum.	Date.	Precipitation. Total.	Days.	Snowfall.[1]	Miscellaneous notes.
Mansfield and Drake.	Near the Ohio River.	1792	.....	.....	.....	−7	Jan. 23	.....	.....	.....	Winter severe; snowfall during January, 24 inches.
		1793	.....	.....	.....	.....	.....	.....	.....	.....	Town flooded; highest river stage 57 feet.
		1794–5	.....	.....	.....	.....	.....	.....	.....	.....	Winters mild.
		1796	.....	.....	.....	−14	Dec. —	.....	.....	.....	Winter severe; Ohio River frozen; frost May 24.
		1797	.....	.....	.....	−18	Jan. 8	.....	.....	.....	Very cold winter; Ohio River frozen entire length.
		1799	.....	103	June 20	.....	.....	.....	.....	.....	Winter severe.
		1800–1802	.....	.....	.....	.....	.....	.....	.....	.....	Winters mild.
		1803–1805	.....	.....	.....	.....	.....	.....	.....	.....	Winters severe.
		1806	..... 54.1	94	.....	9	.....	.....	.....	.....	Winter mild.
		1807	..... 54.4	95	.....	−11	.....	.....	.....	.....	Winter severe; tornado on May 28.
		1808	..... 56.4	98	.....	−4	.....	.....	.....	.....	Winter severe; high river late in December.
		1809	..... 54.4	94	.....	−2	.....	.....	.....	.....	Light frost Aug. 9; tornadoes on May 28.
		1810	..... 52.3	91	.....	−7	.....	.....	.....	.....	Winter mild.
		1811	..... 56.6	96	.....	−8	.....	.....	.....	.....	Strong earthquake December 16.
		1812	..... 52.6	96	.....	−5	.....	.....	.....	.....	Earthquakes on 27 dates.
		1813	..... 52.8	97	.....	−10	.....	.....	.....	.....	Earthquake 2 dates; destructive hailstorm May 4.
Prof. R. S. Bosworth and others.	(Mean temperature) College Hill, (maximum and minimum) Marietta, Ohio.	1814	52.0	.....	.....	.....	.....	.....	.....	.....	Winter mild.
		1815	51.7	.....	.....	.....	.....	.....	.....	.....	Flood in river; highest stage 62 feet, in April.
		1816	51.0	.....	.....	.....	.....	.....	.....	.....	Winter mild; summer dry and cool.
		1817	50.4	.....	.....	.....	.....	.....	.....	.....	Heavy rains; high river in June and November.
		1818	50.4	(99)	.....	(−22)	.....	.....	.....	.....	Heavy snow and very cold in February.
		1819	53.7	(90)	.....	(13)	.....	.....	.....	.....	Winter cold; summer hot.
		1820	52.1	(90)	.....	(0)	.....	.....	.....	.....	Cool year; normal rain and snow.
		1821	51.0	(90)	.....	(−20)	.....	.....	.....	.....	Very cold in January.
		1822	52.2	(86)	.....	(−2)	.....	.....	.....	.....	Winter mild; heavy rains in November.
		1823	51.7	.....	.....	(−7)	.....	.....	.....	.....	Winter cold; summer wet.
		1824	52.5	(94)	.....	(14)	.....	.....	.....	.....	Winter mild and summer warm.
		1825	53.6	(94)	.....	(−6)	.....	.....	.....	.....	Winter mild except for short cold periods.
		1826	53.1	(95)	.....	(−1)	.....	.....	.....	.....	Temperature and precipitation about normal.
		1827	52.9	(95)	.....	(−2)	.....	.....	.....	.....	Heavy rains in December.
		1828	54.0	(94)	.....	(10)	.....	.....	.....	.....	Warm winter, "torrents" of rain and great freshets in January.
		1829	50.8	(92)	.....	(2)	.....	.....	.....	.....	Winter mild except in February.
		1830	53.5	(94)	.....	(−5)	.....	.....	.....	.....	Winter cold; summer hot.
		1831	48.0	(90)	.....	(−10)	.....	.....	.....	.....	January, February, and December very cold.
		1832	51.8	(92)	.....	(−9)	.....	.....	.....	.....	Winter cold; flood Feb. 19, stage 64.2 feet.
		1833	52.5	(95)	.....	(6)	.....	.....	.....	.....	Normal temperature and rainfall.
		1834	52.6	(95)	.....	(0)	.....	.....	.....	.....	Killing frost May 16.

[1] Snowfall for winter ending in year recorded.

Tables of comparative weather data for Cincinnati, Ohio—Continued.

Observers.	Place of observation.	Year.	Temperature. Mean.		Maximum.	Date.	Minimum.	Date.	Precipitation. Total.	Days.	Snowfall.	Miscellaneous notes.
Prof. Ray and others.	Woodward College, Woodward and Sycamore streets, (mean temperature) also at College Hill.	1835	49.2	50.9	95	June 13	−17	Feb. 8	52.15			Winter mild, except part of February.
		1836	49.0	51.2	99	July 23	− 7	Feb. 3	57.39			Wet summer and cold fall.
		1837	50.3	53.0	96	July 15	5	Jan. 3	42.71			6 inches of snow Apr. 4.
		1838	49.5	51.8	100	Aug. 9	−10	Feb. 22	39.45			16.12 inches rain in May and June.
		1839	52.8	54.1	96	July 25	2	Mar. 4	30.62			Dry autumn.
		1840	52.3	53.4	96	July 12	− 1	Jan. 19	47.34		13.3	Warm and wet, February to July.
		1841	52.0	53.9	99	June 12	− 7	Jan. 18	41.05		24.4	Warm summer.
		1842	52.7	53.5	95	June 22	− 5	Feb. 17	41.29		8.8	Zero temperature in December.
		1843	48.8	51.4	98	July 27	− 2	Feb. 7	51.25		28.3	Heavy snows and rains.
		1844	53.0	54.4	94	July 6	− 1	Jan. 29	43.04		10.3	Mild winter and warm summer.
		1845	52.6	53.1	95	July 21	− 6	Dec. 20	46.38		9.0	Rainfall during June 11.50 inches.
		1846	54.0	54.9	96	July 10	0	Feb. 26	53.52		23.6	Warm, dry fall with low river.
		1847	52.0	52.6	92	July 18	− 3	Jan. 8	65.18		28.1	Rainfall, July 8.25 inches, October 9.57 inches, December 8.15 inches.
		1848	52.6	54.0	92	Aug. 14	− 4	Jan. 10	50.58		30.1	"Old fashioned" sleighing in January.
		1849	.....	53.6	92	July 13	2	Dec. 31	52.97		13.9	Heavy rains in July; 18 inches snow in December.
		1850	.....	54.1	96	July 6	0	Feb. 4	54.76		50.0	10 inches snow in January and 19 inches in February.
		1851	.....	54.9	98	July —	− 4	Dec. —	31.70		.....	Dry January; hot summer.
		1852	.....	54.2	98	July —	−12	Jan. —	54.06		.....	Cold January; heavy rains in December.
		1853	.....	54.1	98	June —	2	Feb. —	41.23		.....	An average year.
		1854	.....	56.2	99	Sept. —	5	Jan. —	50.77		.....	High temperature; heavy rains in March.
	Woodward College.	1855	.....	55.1	95	July 20	− 2	Dec. 26	49.40		.....	Very cold in November and December.
		1856	.....	52.8	101	July 17	−14	Jan. 9	25.49		15.8	River frozen Jan. 15 to Feb. 2.
		1857	.....	53.4	95	July 25	−10	Jan. 21	35.25		8.9	Cold January and November; warm December.
		1858	.....	57.2	94	June 29	1	Feb. 23	49.11	104	14.8	Warm January; lowest 28°.
		1859	.....	56.3	101	July 17	− 3	Dec. 8	45.11	102	9.4	Wet spring; rainfall in April 7.53 inches.
Prof. Harper and R. C. Phillips.	Walnut Hills near Eden Park.	1860	.....	56.1	96	July —	− 4	Jan. —	35.17	92	20.3	May 21, severe storm, "hurricane."
		1861	.....	55.9	100	Aug. —	7	Jan. —	43.08	113	8.6	Aug. 21, 3.35 inches rainfall in 2 hours.
		1862	.....	56.3	98	Sept. —	1	Feb. —	38.14	95	18.5	May 21, violent tornado.
		1863	.....	55.4	96	July —	7	Feb. —	40.05	110	39.7	Snowfall in January, 23.5 inches.
		1864	.....	53.9	99	July —	−12	Jan. 1	33.32	115	21.3	May 11, violent snowstorm.
		1865	.....	56.4	98	July —	3	Jan. —	43.98	110	26.2	July 24, severe tornado.
		1866	.....	54.8	92	July —	− 6	Feb. —	49.86	107	5.4	10.88 inches rain in September.
		1867	.....	55.8	95	July —	− 2	Feb. —	30.15	99	21.6	Heavy snows in March, 4.8 inches.
		1868	.....	54.3	99	July —	0	Jan. —	41.60	105	24.2	Heavy snows Apr. 7–9, 3.2 inches.
		1869	.....	55.4	96	Aug. —	5	Mar. —	39.18	98	23.2	Coldest March on record.
		1870	.....	55.8	96	July —	− 8	Dec. 24	27.88	94	19.0	June 29, 2 inches of rain in 30 minutes.
Weather Bureau and Harper.	Pike's Opera House and Walnut Hill.	1871	.....	55.9	96	97 July 9	− 5	0 Dec. 21	32.08	82	12.8	2 inches of rain, 1 hour, Aug. 11.
		1872	.....	54.1	96	96 Aug. 25	− 5	− 8 Dec. 22	34.89	114	19.8	Temperature below zero 3 days in Dec.
		1873	.....	55.1	94	95 June 23	— 1	1 Jan. 30	41.38	145	15.8	Low temperature for March, 1° on the 4th.
		1874	.....	57.0	100	103 July 7	2	6 Jan. 15	37.61	116	18.6	Very warm, temperature above 90° on 47 days.
		1875	.....	53.0	93	96 July 17	−10	− 7 Jan. 10	42.58	148	19.3	Violent sleet storm Mar. 3.
		1876	.....	55.4	98	96 July 18	−10	− 6 Dec. 9	52.62	156	13.0	9.49 inches rain and snow in January.
		1877	.....	56.4	98	92 July 5	— 7	− 4 Jan. 9	34.65	130	17.7	1.33 inches rain in 15 minutes June 25.
		1878	.....	57.0	98	96 July 17	− 6	− 1 Dec. 24	41.62	160	14.4	River rose 20.7 feet in 24 hours Sept. 15.
		1879	.....	56.2	99	98 July 16	−16	−10 Jan. 3	51.60	137	37.5	11.72 inches of rain in August.
		1880	.....	56.9	96	96 July 13	−12	− 5 Dec. 29	54.67	134	10.4	Very cold Nov. 19.
		1881	.....	57.9	103	104 July 10	— 1	2 Jan. 1	47.24	148	39.8	Temperature 101° Aug. 12.
		1882	.....	57.3	95	96 June 25	— 5	1 Dec. 8	52.12	152	16.2	10 inches of snow Jan. 4.
		1883	.....	55.8	96	94 July 22	1	6 Jan. 22	52.35	146	3.6	Crest of flood 66.3 feet, Feb. 15.
		1884	.....	56.3	98	93 June 22	−20	−10 Jan. 5	39.28	151	29.7	Highest river on record, 71.1 feet Feb. 14.
United States Weather Bureau.	United States custom-house and postoffice, Fifth and Walnut Streets.	1885	.....	51.7	.....	97 July 20	.....	−10 Feb. 11	33.94	141	27.3	Lowest average temperature, Feb. and Mar.
		1886	.....	53.0	.....	95 July 29	.....	−12 Jan. 12	31.35	137	21.1	Temperature −3° Dec. 3.
		1887	.....	55.3	.....	101 July 18	.....	− 5 Jan. 3	35.08	127	6.8	Killing frost Apr. 19.
		1888	.....	53.8	.....	97 Aug. 3	.....	6 Feb. 27	34.88	130	10.9	Killing frost Sept. 30.
		1889	.....	54.8	.....	92 July 9	.....	6 Feb. 23	30.92	117	3.3	Driest August on record, 0.26 inch of rain.
		1890	.....	56.4	.....	96 June 28	.....	7 Mar. 6	47.70	162	7.4	Warm winter.
		1891	.....	54.7	.....	92 Aug. 9	.....	4 Feb. 4	38.44	138	16.0	Coolest July on record.
		1892	.....	53.3	.....	98 July 24	.....	2 Dec. 27	31.95	135	15.7	"Old fashioned" white Christmas.
		1893	.....	53.7	.....	95 July 30	.....	−11 Jan. 15	44.00	141	29.8	Ohio frozen; first time since 1881.
		1894	.....	56.1	.....	96 Aug. 9	.....	− 4 Jan. 25	26.59	124	18.9	Rain in July, 0.13 inch; dryest month on record.
		1895	.....	53.6	.....	97 June 3	.....	−12 Feb. 8	29.33	110	36.0	3.57 inches rain in 24 hours Jan. 6–7.
		1896	.....	55.6	.....	96 Aug. 6	.....	− 2 Feb. 20	34.48	127	29.3	Maximum wind, 50 miles, Aug. 1.
		1897	.....	55.3	.....	98 July 4	.....	−10 Jan. 25	43.89	121	13.8	Crest stage of flood, 61.2 feet, Feb. 26.
		1898	.....	55.9	.....	98 July 3	.....	1 Feb. 3	38.97	133	13.0	Crest stage of flood, 61.4 feet, Mar. 29.
		1899	.....	55.0	.....	99 Sept. 6	.....	−17 Feb. 9	34.69	125	24.9	Record temperature for Sept., 99°.
		1900	.....	56.0	.....	97 Sept. 10	.....	− 5 Feb. 25	27.78	119	9.7	Thunderstorms on 15 days in August.
		1901	.....	54.0	.....	105 July 22	.....	− 7 Dec. 15	17.99	111	9.3	Driest year on record.
		1902	.....	54.7	.....	96 July 17	.....	0 Feb. 3	37.30	125	17.7	2.26 inches of rain in 1 hour May 20.
		1903	.....	54.3	.....	96 July 10	.....	− 1 Feb. 17	34.69	133	17.9	Heavy thunder squals July 21.
		1904	.....	53.2	.....	94 July 17	.....	0 Feb. 16	29.54	111	15.0	Very little rain July and August.
		1905	.....	54.2	.....	94 June 19	.....	− 5 Feb. 13	38.69	127	22.9	Violent thunderstorms May 11.
		1906	.....	55.4	.....	94 June 29	.....	0 Feb. 6	40.83	147	29.2	Record temperature for January, 75°.
		1907	.....	54.2	.....	95 July 6	.....	4 Jan. 26	44.56	142	15.8	Crest stage of flood, 65.2 feet, Mar. 19.
		1908	.....	56.6	.....	98 Aug. 16	.....	3 Feb. 2	27.29	113	9.7	Drought from Aug. 18 to Nov. 9.
		1909	.....	54.9	.....	95 Aug. 28	.....	− 3 Dec. 30	37.43	130	14.3	Light frost May 11.
		1910	.....	54.4	.....	95 June 19	.....	1 Feb. 19	34.42	107	40.4	20.6 inches of snow in February.
		1911	.....	56.7	.....	102 July 4	.....	10 Jan. 4	45.05	140	20.7	Record temperature for May, 95°, on the 27th.
		1912	.....	53.7	.....	96 July 24	.....	− 9 Jan. 7	38.61	131	25.5	Very cold Jan. 4 to 13.
		1913	.....	57.0	.....	101 July 30	.....	6 Feb. 6	42.15	130	9.6	Great floods, crest 70 feet, on Apr. 1.
		1914	.....	55.4	.....	103 July 12	.....	− 3 Dec. 15	32.78	108	28.6	21.4 inches of snow in February.
		1915	.....	53.7	.....	95 July 31	.....	2 Jan. 24	41.30	136	20.4	Destructive cyclone July 7.
		1916	.....	55.5	.....	99 July 27	.....	0 Jan. 17	34.66	129	19.8	Hot wave and drought July and August.
		1917	.....	52.4	.....	95 Aug. 1	.....	−10 Dec. 11	36.07	122	25.4	Great ice gorge, began Dec. 11.
		1918	.....	55.4	.....	102 Aug. 6	.....	−13 Jan. 12	41.10	111	37.7	Two floods, 61.2 and 61.8 feet; gorge broke Feb. 12.
		1916	53.5	.....	98	..... July 28	— 4	..... Jan. 17	38.14	136	26.7	4.5 inches snow, Apr. 8–9.
		1917	50.4	.....	94	..... July 31	−13	..... Dec. 11	35.32	129	27.6	Lowest temperature on record for December.
		1918	53.6	.....	101	..... Aug. 6	−16	..... Jan. 12	40.88	131	38.0	Lowest temperature for January since 1797.

*A Abbe Meteorological Observatory, La Fayette Circle, Clifton; last three years.

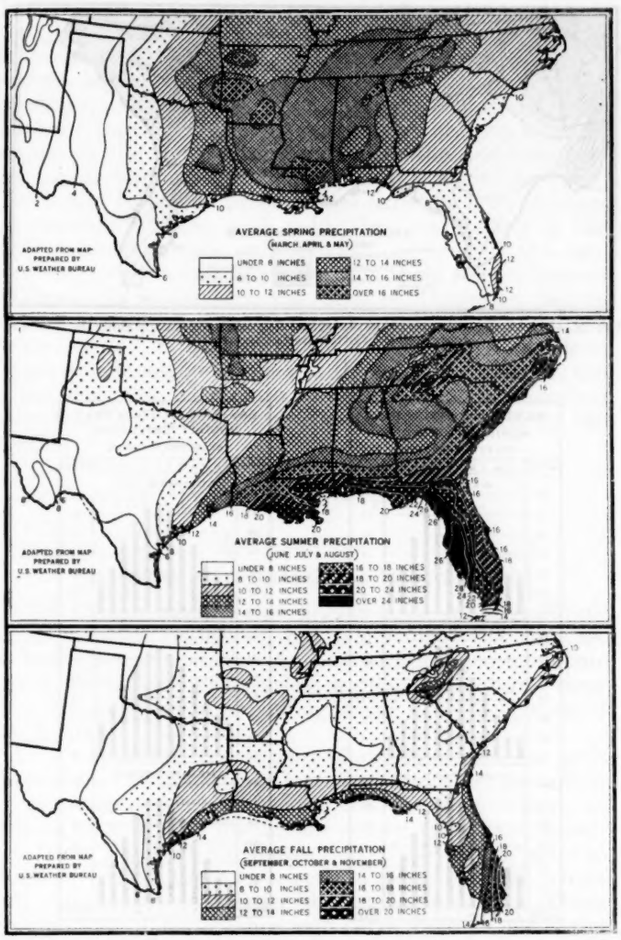
NOTE.—Temperatures, (mean, maximum and minimum) first columns for hilltops, second columns for lower part of city.

CLIMATE OF THE COTTON BELT.

By O. C. STINE and O. E. BAKER.

[Reprinted from Atlas of American Agriculture, Part V, Sec. A (Cotton), Office of Farm Management, U. S. Department of Agriculture, Washington, D. C., issued Dec. 15, 1918.]

Although the most noticeable differences in the density of cotton acreage and variations in yield per acre within the Cotton Belt are due principally to soil conditions, the outer boundaries of cotton production are determined almost entirely by climatic factors. The Cotton Belt has an average summer temperature of 77° along the northern boundary. (See fig. 28.) This temperature appears to be the limit beyond which commercial production becomes unprofitable. (A very little cotton is grown for household use by the mountaineers in eastern Kentucky, where the summer temperature is only 74°.) In the southern portion of the Cotton Belt the summer temperature is 80° to 85°, and in the Imperial Valley of California it averages 95°. Along the northern margin of the Cotton Belt the last killing frost in spring occurs, on the average, about April 10, and the first killing frost in fall about October 25, so that the frostless season is about 200 days. In the southern portion of the Cotton Belt the last killing frost in spring occurs about March 10, on the average, and the first killing frost in fall seldom before November 25, the frostless season being 260 days or more in length. (Figs. 25–27.)


AVERAGE SPRING PRECIPITATION
(MARCH APRIL & MAY)
UNDER 8 INCHES
8 TO 10 INCHES
10 TO 12 INCHES
12 TO 14 INCHES
14 TO 16 INCHES
OVER 16 INCHES
ADAPTED FROM MAP PREPARED BY U.S. WEATHER BUREAU
AVERAGE SUMMER PRECIPITATION
(JUNE JULY & AUGUST)
UNDER 8 INCHES
8 TO 10 INCHES
10 TO 12 INCHES
12 TO 14 INCHES
14 TO 16 INCHES
16 TO 18 INCHES
18 TO 20 INCHES
20 TO 24 INCHES
OVER 24 INCHES
ADAPTED FROM MAP PREPARED BY U.S. WEATHER BUREAU
AVERAGE FALL PRECIPITATION
(SEPTEMBER OCTOBER & NOVEMBER)
UNDER 8 INCHES
8 TO 10 INCHES
10 TO 12 INCHES
12 TO 14 INCHES
14 TO 16 INCHES
16 TO 18 INCHES
18 TO 20 INCHES
OVER 20 INCHES
ADAPTED FROM MAP PREPARED BY U.S. WEATHER BUREAU

FIGS. 16 to 18.—In spring the rainfall is heaviest in the Mississippi Valley, and in summer along the Gulf and Atlantic coasts. In autumn, during picking time, the rainfall throughout the Cotton Belt averages less than 12 inches, and is mostly under 10 inches.

The average annual precipitation in the Cotton Belt ranges from 23 inches in western Oklahoma and Texas to 55 inches in eastern North Carolina and 60 inches in southern Mississippi, but throughout much of the Belt is between 30 and 50 inches (fig. 19). The spring rainfall ranges from 6 inches in western Texas to 16 inches in Arkansas and southern Mississippi, being heavier in the Mississippi Valley States than in Texas or the south Atlantic States (fig. 16). The summer rainfall is somewhat greater than that of the other seasons, especially in the southern and eastern portion of the Belt, reaching a maximum of 20 inches in southern Mississippi and in eastern North and South Carolina; while in the Black Prairie of Texas the amount received averages only 8 inches (fig. 17). Autumn is the driest season of the year, practically all the important cotton regions receiving less than 10 inches of rain during the fall months (fig. 18). February and November are the wettest months in

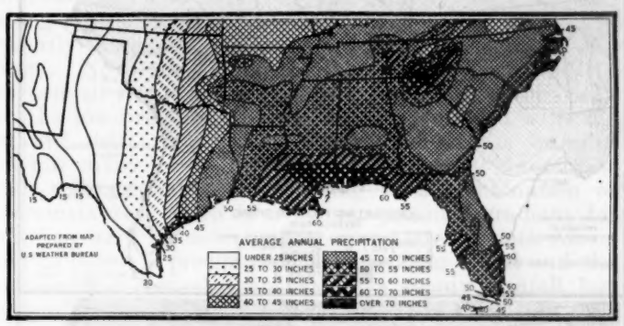

AVERAGE ANNUAL PRECIPITATION
UNDER 25 INCHES
25 TO 30 INCHES
30 TO 35 INCHES
35 TO 40 INCHES
40 TO 45 INCHES
45 TO 50 INCHES
50 TO 55 INCHES
55 TO 60 INCHES
60 TO 70 INCHES
OVER 70 INCHES
ADAPTED FROM MAP PREPARED BY U.S. WEATHER BUREAU

FIG. 19.—The average annual precipitation in the Cotton Belt ranges from 20 to 60 inches, but is mostly from 30 to 50 inches. The heaviest annual rainfall occurs in southern Alabama and Mississippi.

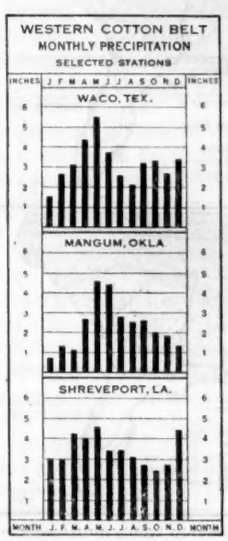

WESTERN COTTON BELT
MONTHLY PRECIPITATION
SELECTED STATIONS
INCHES J F M A M J J A S O N D INCHES
WACO, TEX.
MANGUM, OKLA.
SHREVEPORT, LA.
MONTH J F M A M J J A S O N D MONTH

FIG. 20.

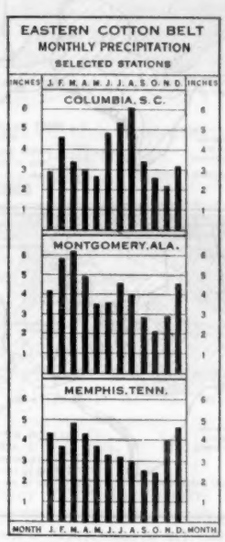
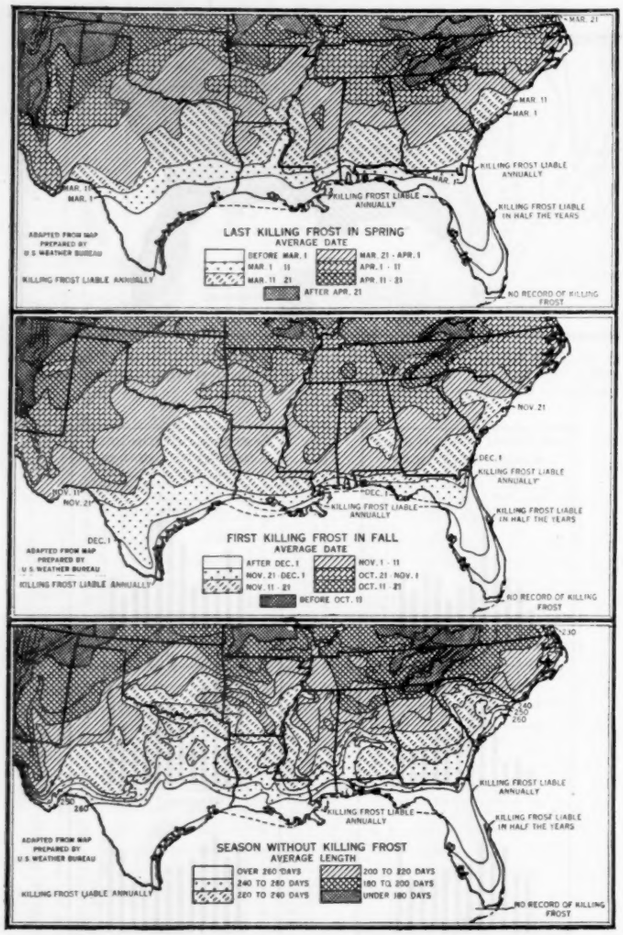

EASTERN COTTON BELT
MONTHLY PRECIPITATION
SELECTED STATIONS
INCHES J F M A M J J A S O N D INCHES
COLUMBIA, S. C.
MONTGOMERY, ALA.
MEMPHIS, TENN.
MONTH J F M A M J J A S O N D MONTH

FIG. 21.

the Mississippi Valley States, in Alabama, and in northern Georgia. August is the wettest month in the Carolinas and May in Texas and Oklahoma. October and November are the driest months throughout practically the entire Cotton Belt.

Weather conditions favorable for cotton.—The best conditions for cotton production are found where a mild spring with light but frequent showers merges into a moderately moist summer, warm both day and night, followed by a dry, cool, and prolonged autumn. Too cool weather in the spring retards growth, and too much rain may induce the seed to rot rather than to germinate, or later cause the development of surface roots to the sacrifice of the deeper roots, with resultant wilting and shedding of leaves and bolls during drought in summer. May and June particularly are critical months, when heavy rainfall, especially if accompanied by low temperatures, is very detrimental. Rainy weather in these months also interferes with cultivation. On the other hand, drought in the spring and early summer often kills the young shallow-rooted seedlings. A wet summer promotes vegetative growth, or "weed," at the expense of boll production, and favors the growth of weeds, while drought stunts the plants, causes early maturity, and reduces the yield, as does also a spell of cool weather. The most unfavorable conditions for the crop are a cool and wet May and June followed by a hot and dry July and August. The ideal rainfall is of the thundershower type with several days of bright, warm weather between rains. Plenty of sunshine is especially important in June and early July when the plants are in bloom. As the cotton matures and the bolls begin to open, in the latter part of August, rainy weather is undesirable, as it retards maturity, interferes with picking, and discolors or damages the exposed fiber. Moderate rain in in early September, however, favors the production of a large "top crop" of late maturing bolls. The greater daily range in temperature in a dry fall is also favorable to the maturing crop as it checks vegetative growth and induces fruiting. Early frost in the fall kills the "top crop" on the upper branches of the plant, or causes the bolls to open prematurely, often seriously reducing the yield. In northern Texas and Oklahoma, where the winds dry out the cotton in the unopened frost-bitten bolls, this "top crop" is "snapped" from the stalks, and, after being run through a machine which removes the burrs, is ginned and sold as "bollies." In other sections rains may cause the frost-bitten bolls to rot.

Dates of planting and picking (see maps, *Monthly Weather Review*, May, 1919, 47:318).—Cotton planting generally begins in the southern portion of the Cotton Belt about March 20, and progresses northward with the


LAST KILLING FROST IN SPRING
AVERAGE DATE
BEFORE MAR. 1
MAR. 1 - 11
MAR. 11 - 21
MAR. 21 - APR. 1
APR. 1 - 11
APR. 11 - 21
AFTER APR. 21
KILLING FROST LIABLE ANNUALLY
KILLING FROST LIABLE IN HALF THE YEARS
NO RECORD OF KILLING FROST
FIRST KILLING FROST IN FALL
AVERAGE DATE
AFTER DEC. 1
NOV. 21 - DEC. 1
NOV. 11 - 21
NOV. 1 - 11
OCT. 21 - NOV. 1
OCT. 11 - 21
BEFORE OCT. 11
SEASON WITHOUT KILLING FROST
AVERAGE LENGTH
OVER 260 DAYS
240 TO 260 DAYS
220 TO 240 DAYS
200 TO 220 DAYS
180 TO 200 DAYS
UNDER 180 DAYS
ADAPTED FROM MAP PREPARED BY U.S. WEATHER BUREAU

FIGS. 25–27.—The average length of the season between killing frosts varies from 200 days along the northern margin to 260 days or more in the southern portion of the Cotton Belt.

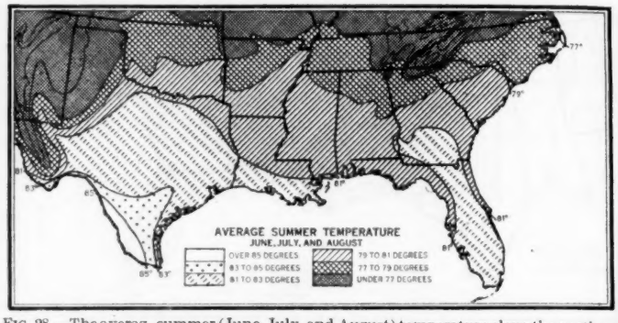


FIG. 28.—The averag summer (June, July, and August) temperature along the northern margin of the Cotton Belt is about 77° (F.).

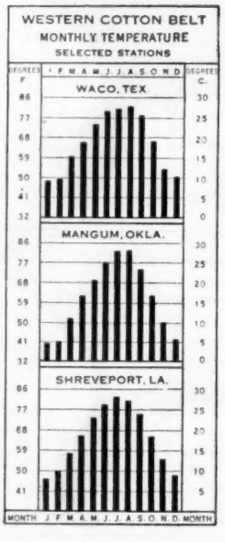


FIG. 29.

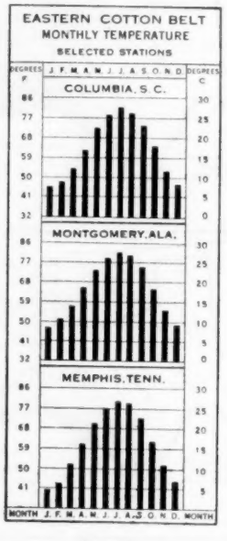


FIG. 30.

advance of temperature at the rate of 10 to 20 miles a day, so that in the central portion planting begins during the first week in April, and in the northern portion about April 20. The planting usually requires two to three weeks to complete, hence is over in the southern districts about April 15 and in the northern districts a month later. When the cotton is a few inches high the rows need to be thinned, which process is known as "chopping out," and is the most laborious task in the cultivation of cotton except that of picking. Chopping out begins in the southern districts of the Cotton Belt usually about the 1st of May, in extreme southern Texas as early as April, and continues for about a month. In the northern districts it begins about June 1 and ends from June 20 to July 5, being usually two weeks later in Arkansas and western Tennessee, especially on the river bottom lands, than at corresponding latitudes in the Carolinas. Cotton picking begins about August 10 in the southern portion of the belt, usually the last week in August in the central portion, and in the northern portion about September 10. The cotton is picked by hand, a slow and laborious process, and three or four pickings are commonly given each field, the first picking of the early maturing bolls and the last picking of the late maturing bolls being much smaller than the midseason pickings. It is usually the first of December before picking is completed in the southern districts and from December 20 to January 1 in the northern districts. Where the acreage is large and the labor insufficient, the picking may drag along into midwinter, though the cotton is by this time likely to be considerably injured by the weather.

THE CLIMATE OF SOUTH AFRICA.

By H. E. WOOD.

[Extracts from The South African Geogr. Journ., 1918, 2:5-8.]

* * * In winter the pressure system over South Africa strongly resembles, but is not quite the same as, an anticyclonic system. And as within an anticyclonic region, there is no well-marked wind system, so in winter there are no definite prevailing winds over the Union of South Africa.

As we approach the fringes of the high pressure area the tendency of the wind to have a well-marked prevailing direction increases. Thus, on the northern fringe, at Bulawayo, the wind during the winter months is generally from the east-southeast. At Cape Town, on the southern fringe, there is a certain percentage of winds from the northwest during the winter months. These directions are in accordance with Buys-Ballot's law of the winds according to which, in the Southern Hemisphere if one is standing back to the wind, the higher pressure is on the left hand, the lower on the right.

In general, it may be said that the wind system over the Union in the winter months is such that the surface air tends to move outward. This explains the general absence of rainfall over the Transvaal, the Free State, Natal, and the greater part of Cape Colony during the winter. The air is moving over the surface of dry land, and has no opportunity of becoming laden with moisture. The conditions are rather different over the southwest corner of the Union or the Western Province of Cape Colony. The northwest wind which frequently blows here has traveled for some considerable distance over the South Atlantic Ocean and brings with it some rain to the Cape.

The summer conditions over the Union are of a more complicated character. In the first place, owing to the coming south of the sun the high-pressure belt is pushed south over ocean and land. Further, owing to the greater absorption of solar radiation by the land, the temperature of the land surface becomes higher than that of the ocean on either side. The result is that the high-pressure belt which extends across the land during the winter months now breaks and a large tongue from the equatorial low-pressure belt pushes its way in and lies over South Africa. Thus in the summer months (October-February) the barometer over the interior of South Africa is rather lower than round the coasts, east, west. and south. The barrier of moderately high pressure along the south coast is, however, very weak, and is frequently broken through by cyclones passing off the coast. Now, there is on the whole, an inward draft of surface air from the high-pressure regions over the ocean to the low-pressure system over the land and with the inward drift moisture is brought in to the interior. In not many cases, however, does this fall directly as rain. Occasionally when, owing to a combination of circumstances, there is a strong pressure gradient for northeasterly winds extending over eastern South Africa the moisture is precipitated at once over Natal and the eastern and central Transvaal in a steady rainfall, but generally the precipitation of moisture does not take place directly.

In the great tongue of low pressure over the interior, where the pressure gradient is small and there is very little lateral movement of the surface air, the effect of intense solar radiation is to give rise to local vertical movements of the atmosphere. These are evident in the great cumulus clouds which grow generally during the summer afternoons. * * *

The general direction of motion of the thunderstorms across country is from southwest to northeast.

The summer rainfall over the interior of South Africa may thus be divided into two classes (*a*) the steady rains, which are associated with northeasterly winds and a fairly steep pressure gradient, and (*b*) the thundershowers, which occur with very shallow gradients. The steady rains can be forecast as they follow a well-marked distribution of pressure, but it is a very difficult matter to forecast by even a few hours the occurrence of thunderstorms. Thunderstorm conditions may exist over a huge area of country, but the actual falls of rain are very localized: Johannesburg may have a great downpour of rain whereas Pretoria, a little over 30 miles away, may not receive a drop.

The great frequency of summer thunderstorms over South Africa is due partly to the intense solar radiation and probably also partly to the generally bare character of the country. If the country were more wooded it is quite probable that evaporation would be so modified that the rainfall would be more distributed and lighter in character and the frequency of thunderstorms less. Over the Witwatersrand district 56 per cent of the rainfall is distributed by heavy showers of over one-half inch in amount, whereas at Greenwich, England, only 25 per cent falls similarly in heavy showers.

The region over which rain falls in the winter months is very limited, and is practically confined to the Western Province of the Cape. Such rainfalls are probably associated with cyclonic systems which approach South Africa from the South Atlantic Ocean. Owing to the presence of the high pressure core over the land they can rarely penetrate into the interior and are forced to skirt the

coast. Also as they have traveled over an ocean surface, which is at a rather low temperature, their moisture contents are small, and they lose practically all their moisture when they strike the extreme southwest of Africa. The northeasterly winds which prevail during the summer months have traveled over much warmer water surfaces and, although they deposit the greater amount of their moisture along the Drakenberg Range, which runs parallel to the East Coast, have sufficient left to convey moisture well into the interior. The result of this is that the western half of the Union is, on the whole, much drier than the eastern half. The strip of land along the Natal coast has a rainfall of between 35 and 50 inches per annum, whereas the greater part of the Cape Province, excepting the southwest and south coastal regions, receives only between 5 and 15 inches a year.

Roughly speaking, the mean annual temperature over all parts of the Union is very nearly the same. The higher temperature which would naturally result from an interior situation is almost balanced by the effect due to the greater elevation of the interior. For example, whereas the mean annual temperature at Capteown is 62°, that at Bloemfontein, the altitude of which is 4,400 feet, is 61°.

The variations of temperature are, however, much greater over the interior than at coastal places. Frosts are practically unknown near the coast, but over the interior, owing to the intense radiation from the earth during the dry clear nights they are of frequent occurrence between May and September.

At Capetown, the average shade maximum temperature in January is 78.5°, and the average shade minimum in July is 47.2°, the difference being 31.3°. At an interior town, Kimberley, the average shade maximum in January is 90.5° and the average shade minimum in July is 36.5°, a difference of 54°. The diurnal range of temperature at an interior station as against a coastal station is even more marked than this.

Owing to the fact that the warm Mozambique current flows down the East Coast of South Africa whereas the cold Benguela current flows up the West Coast, the temperatures along the East Coast are higher than those along the West Coast. Durban and Port Nolloth are in very nearly the same latitude, but the mean annual temperature at Durban is 70.8°, that at Port Nolloth 57.5°. It is chiefly due to the influence of this current that the climate of the coastal strip of Natal is rather more tropical than semitropical.

AUSTRALIAN RAINFALL.[1]

HUNT, H. A., Editor. **Results of rainfall observations made in South Australia and the Northern Territory, including all available annual rainfall totals from 829 stations for all years of record up to 1917.** 421 pp.; maps, diagrs. Bur. of Meteorol., Commonwealth of Australia, Melbourne, 1918. 10s. 6d. 12 x 9½.

The activity of the Australian Commonwealth Bureau of Meteorology is remarkable. A steady stream of important publications continues to flow to the reviewer's desk. Even the war brought no interruption, only delay. The present volume is one of a series, of which three numbers (New South Wales, Victoria, and Queensland) have already been issued, leaving two more still to come (Western Australia and Tasmania). In the issue before us we have tabulations of all the available annual totals of rainfall and of wet days for 829 stations—surely a very large number considering the area concerned—up to the year 1917. For about 200 stations there are also monthly totals to 1915. Such complete information for these sections of Australia has not before been embodied under one cover. Owing to delays due to the war the annual totals for 1916 and 1917 appear in supplementary form. In order to have the work complete for reference and for comparison, authentic annual (for the individual years 1878–1917) and also average annual and monthly rainfall and monthly rainfall maps are included. There are notes on the annual variation and monthly distribution of the rainfall, and a record of notable meteorological events. The incidence of the summer and winter rainfalls and the resultant wheat yields in South Australia are given special attention, the data being presented in both tabular and map form. The monthly and annual meteorological elements and normals for Adelaide and Darwin are given in appendixes.

This mere enumeration of the contents of the volume will serve to show how very complete and extensive is the informatuon it contains. There is a remarkable abundance of excellent maps and of diagrams. While the details are of immediate concern only to those who are making special studies of Australian weather and climate, the volume is one which surely deserves mention in the Review. Those who, for one reason or another, have occasion to look up the rainfall conditions of the Australian Commonwealth will realize their lasting indebtedness to Mr. Henry A. Hunt and to his excellent staff of assistants and observers.—*R. DeC. Ward.*

[1] *Reprinted from* Geographical Review, New York, June, 1919, p. 432.

THE AUSTRALIAN ENVIRONMENT ESPECIALLY AS CONTROLLED BY RAINFALL.[1]

By Dr. GRIFFITH TAYLOR,

Commonwealth Bureau of Meteorology.

[Review—Summary[2] by Dr. S. S. Visher, Indiana University.]

This excellent treatise is the third of a series dealing with climatic control of settlement and production in Australia.[3] It is primarily a systematic study of the rainfall of Australia. The rainfall of each of the 15 regions into which the area is divided for the purpose of this study is discussed in some detail. The annual average precipitation for each section is shown in detail by isohyets, lining, and stippling on brown, relief maps (scale 1:5,000,000), compiled by Dr. Taylor.[4] Graphs of the distribution of rainfall throughout the year are given for several stations in each section. Conclusions as to the important sources of rainfall were derived from a study of the daily weather maps for the five-year period

[1] The Australian Environment (especially as controlled by rainfall). A regional study of the topography, drainage, vegetation and settlement; and of the character and origin of the rains. By Griffith Taylor, Physiographer in the Commonwealth Bureau of Meteorology, Commonwealth of Australia. Advisory Council of Science and Industry, Memoir 1, large 4to (10 by 12 in.) 25 by 31 cm., 188 pp., 15 colored contour maps, a Solar Control Model; 111 typical daily weather charts, 15 annual rainfall groups, and 42 other maps and diagrams. Selected bibliography. Government Printer, Melbourne, 1918.

[2] Cf. other reviews: *Scottish Geogr. Mag.*, July, 1919, pp. 259–261; *Nature* (London), Aug. 7, 1919, pp. 447–448; *Quart. Journ. Roy. Meterological Soc.*, July, 1919, pp. 260–261.

[3] The other two memoirs in the series are "The Control of Settlement by Temperature and Humidity," Bulletin 14 of the Meteorological Bureau, 1916, and "The Climatic Control of Australian Production," Bulletin 11 of the Meteorological Bureau (reviewed in *Geographical Review*, Nov. 1917, pp. 401–403, and Jan. 1918, p. 86). See also "The Settlement of Tropical Australia," *Monthly Weather Review*, 1917, 589–590; and "The Climatic Factors Influencing Settlement in Australia," 14 pp., in *Year Book of the Commonwealth of Australia*, No. 11, 1918.

[4] The maps here published were the basis of the first official orographical map of Australia, recently issued by the department of lands at Sydney.

NOTE.—The prompt publication of the present memoir by the bureau in which it was prepared being prevented by lack of funds, it was published by the Council of Science and Industry.

1910–1914. "The origin of the rainfall" is illustrated by approximately eight "typical charts" for rainy days for each of the 15 districts, one or two for each of the more important types of pressure conditions accompanying widespread rains.

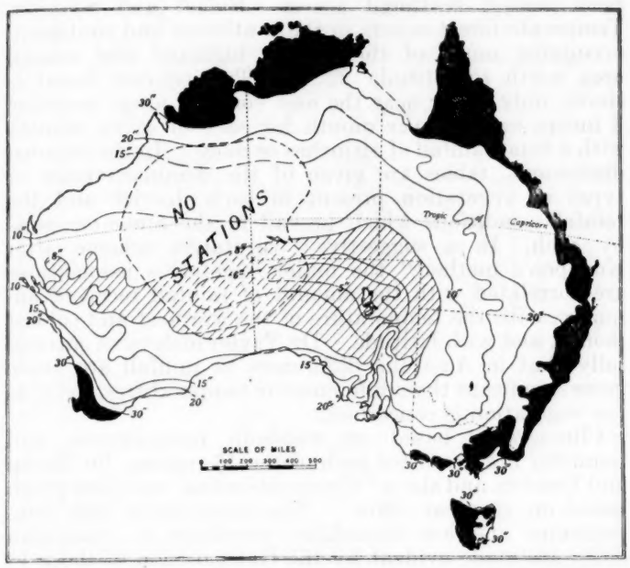


FIG. 1.—Average annual rainfall of Australia revised to 1916. Over 30 inches shown in black; the driest region (under 8 inches) is ruled. (The records in central West Australia are still too short for accuracy.)

An average-rainfall map revised to 1916 is reproduced as figure 1. More than two-thirds of Australia receives less than 15 inches and nearly one-fourth receives less than 8 inches. These drier portions are mainly in the interior. The sectional maps show that small coastal areas in northern and northeastern Australia receive more than 50 inches of rain and a few localities more than 60 inches. (See fig. 2.)

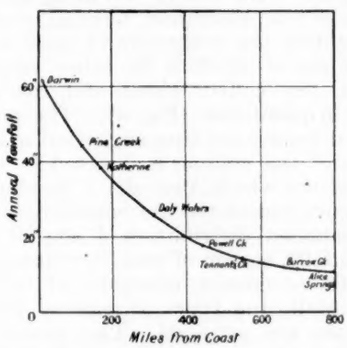


FIG. 2.—Relation of rainfall in Northern Territory to the distance from the coast.

The march of the rain belt is illustrated cleverly by "A solar control model." By sliding a cardboard up and down, the change in the amount of rainfall received each month is shown approximately by the shifting of belts of 1 to 2 inches and over. These belts are visible through an opening the shape of Australia. Other things shown on the movable cardboard are the 70°-isotherm (approximate); the trade-wind belt, belt of variables, belt of westerlies and "a line of centers of HIGHS." This last forms the indicator, it being placed opposite the required month as printed beside a slot. This line of the centers of HIGHS passes almost through Perth and Brisbane in midwinter and across the southern tip only in midsummer. For Australia there is a lag of five weeks. (Fig. 3.) There is very evident correspondence between the rainfall conditions of any month as

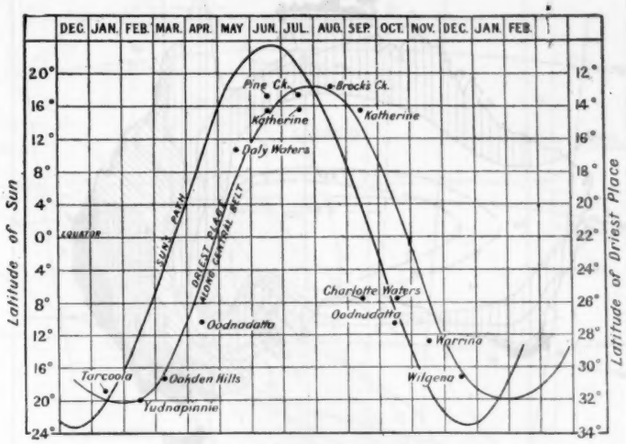


FIG. 3.—Relation of sun's march between tropics to the march of the rain belt. (Driest spot in each month being used as index.)

shown by this device and as mapped on inserts for January, April, July, and October, on the corners of the model. This model illustrates strikingly the solar control of rainfall in Australia and the interdependence of meteorological phenomena. Hence it is not surprising that Prof. Taylor

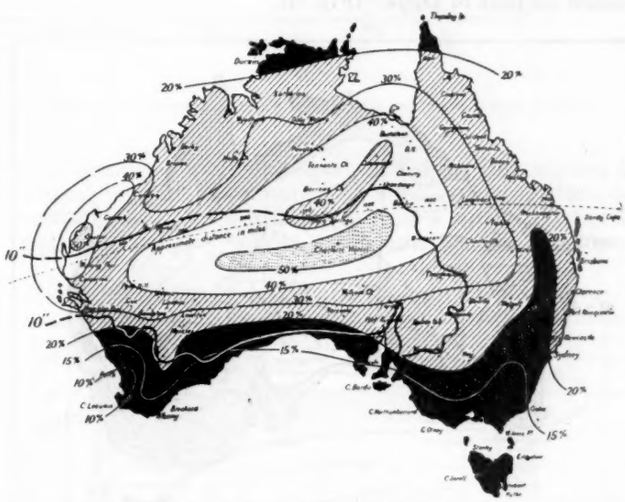


FIG. 4.—Rain reliability isopleths for Australia. The figures show the percentage variations from the normal annual rainfall (1891–1910.)

has found it helpful in his teaching at Melbourne University.

Rain reliability (fig. 4) and rain uniformity (fig. 5) are mapped for the first time for Australia. These maps differ greatly though both resemble most other maps of Australia in possessing a conspicuous contrast between coast and interior. At Onslow, near the western coast, just north of the Tropic, the annual rainfall has ranged from less than 1 inch in 1896 and 1912 to 19 inches in 1881 and

27 inches in 1900. The average rainfall there (1886 to 1916) is about 10 inches, but how little biologic significance is an average when derived from so erratic a series! The abnormal rainfalls at Onslow are related to occasional tropical hurricanes.

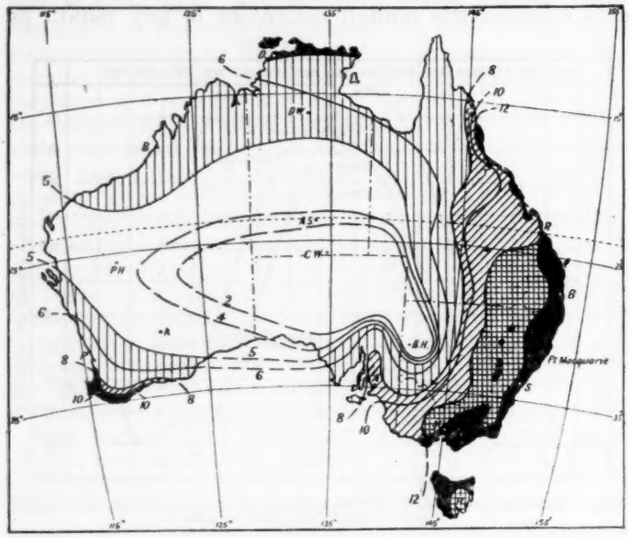


FIG. 5.—Rainfall uniformity. Isopleths show number of months receiving over 1 inch of rainfall. (Black areas receive 1 inch additional during each of seven months as well as 1 inch each month of year.)

The rainfall uniformity map (fig. 5) shows by isopleths the number of months receiving over 1 inch of rainfall.

Dr. Taylor presents a vegetation map of Australia based on that of Diels. (Fig. 6).

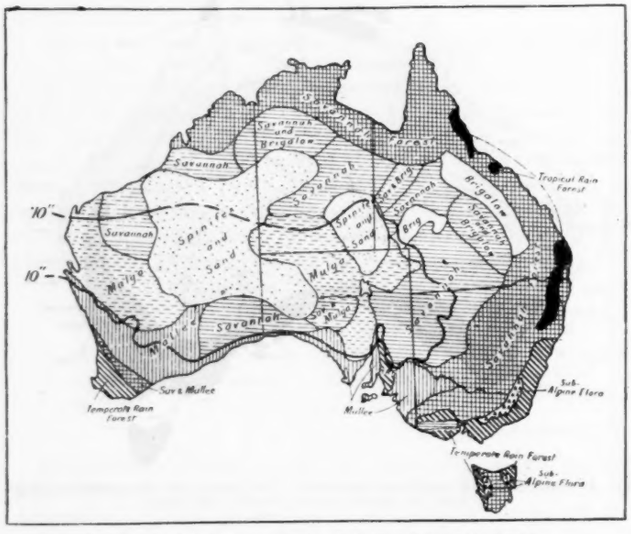


FIG. 6.—Vegetation map for Australia, based on that of Diels.

Savannah forest occurs even in regions having somewhat more than 50 inches of rainfall where during several months less than 1 inch of rain is received; for example, at the northern tip of Australia where for five months less than 1 inch per month falls and yet the annual rainfall is more than 60 inches. Comparison with the rainfall maps reveals that in tropical Australia a rainfall of approximately 25 inches is required for Savannah forest, but that in the cooler southeast such forest occurs where as little as 15 inches is received. Savannah, with acacia locally important, extends to the 10-inch isohyet at some points in the north, but quite generally reaches the 8-inch isohyet at the south and occurs near Lake Eyre with 5 inches of rain. Most of the drier portions of the continent possess scattered acacia (*Mulga*) and *Spinifex*. Temperate forest occurs in the southwest and southeast, occupying much of the eastern highland and coastal area north to latitude 32° S. Tropical-rain forest is shown only on or near the east coast in areas receiving 2 inches or more per month for each of seven months with a total rainfall of 40 inches or more. In the regional discussions, tables are given of the dominant trees or types of vegetation present in each district and the rainfall conditions which prevail in the areas occupied by each. In a suggestive "vegetative scheme after Koeppen's method" the major vegetative associations are correlated with the amount of rainfall received annually, with the temperature of the warmest and coldest month, and with latitude. Dr. Taylor maintains successfully that in Australia differences in rainfall are much more significant than differences in temperatures, so far as the vegetation is concerned.

Climographs based on wet-bulb temperatures and humidity are given for each of the 15 regions, for Berlin and London, and also a "Composite white race climograph based on 12 great cities." The particularly high temperatures and low humidities prevalent in Australian cities are made evident by the transposition of these 18 climographs on one page. (Fig. 7.) Dr. Taylor defends his use of wet-bulb instead of dry-bulb temperatures by the statement that "my 'tentative scale of discomfort'—which is the feature arousing most interest in Australian circles—is much more accurately indicated by wet-bulb than by dry-bulb. The conditions along our tropical coast seem to agree fairly with this scale. I shall be glad to hear how it applies in other hot regions."

An extension of the climograph method is made in the hythergraph, a graph made by plotting the average monthly temperature on one axis and the average monthly rainfall on the other. Hythergraphs have been prepared for seven Australian tropical stations and a graph representing the composite of these is transposed on hythergraphs of stations in other tropical regions where cotton, tea, coffee, wheat, and, rice respectively, are produced in quantities. (Fig. 8). The possibilities of the Australian tropics are thus suggested in a novel way.

Five-sixths of the volume is devoted to the study of the 15 regions into which Australia is divided. For each region the topics considered are boundaries, topography, drainage, vegetation, distribution of rainfall, topographic effect (on rainfall), season of rain, correlation with other regions, health, economics, character of rainfall, annual history of rainfall, and types of regional rain. Most of the boundaries are artificial. The major division is between the summer rain region and the winter rain region. The topography is discussed briefly but apparently skillfully. Quotations concerning regions Dr. Taylor does not know well are frequent. Correlation with other regions is done by tables of "homoclines," the data for foreign stations being taken chiefly from Hann. (See Table 1.) The distribution of rainfall throughout the year is shown clearly by annual rainfall graphs of several stations in each district. The "character of rainfall" concerns the type of pressure conditions bringing the rain, some 1,500 daily weather maps for 1910–1914 furnishing the data.

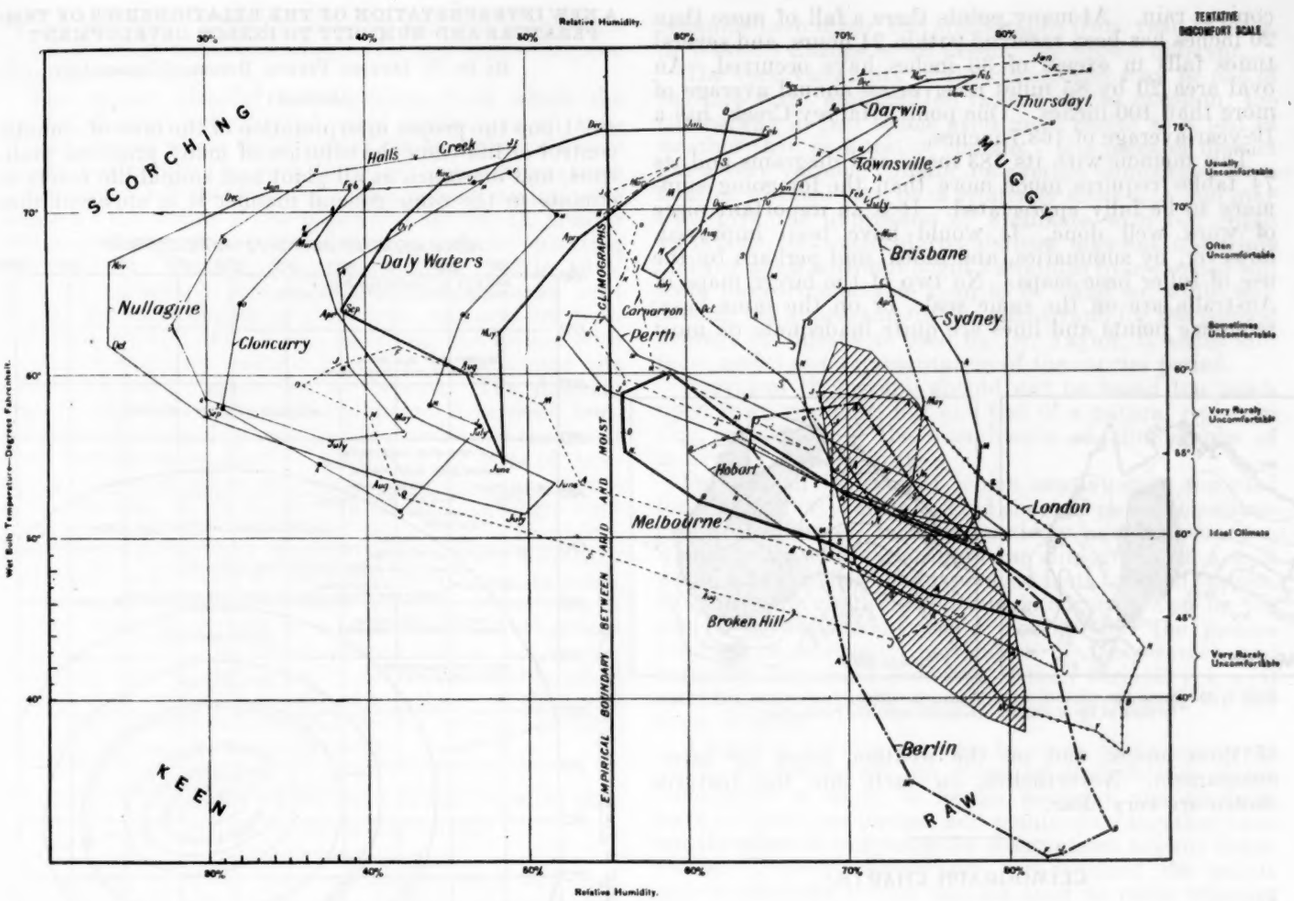


FIG. 7.—Typical climographs for Australia. (London and Berlin added for comparison.) The empirical boundary between arid and moist regions is given.
NOTE.—The shaded figure is the composite white race climograph based on 12 typical cities.

TABLE 1.—*Homoclines of East Victoria.*

	Monthly rainfall.			Monthly temperature.		
	Wettest.	Driest.	Annual.	Hottest.	Coldest.	Annual
	Inches.	*Inches.*	*Inches.*	*° F.*	*° F.*	*° F.*
Melbourne	2.64 (Oct.)	1.74 (Feb.)	25.5	67.5	48.4	58.3
Hamilton	3.34 (June)	0.95 (Feb.)	26.9	66.4	46.0	55.8
San Francisco	4.5 (Jan.)	.1 (July)	22.5	59.0	50.1	56.0
Portland, Oreg	7.4 (Dec.)	.6 (July)	45.0	67.0	39.0	53.0
Valparaiso	7.0 (July)	.0 (Feb.)	24.0	63.5	52.7	57.7
Oporto, Portugal	6.0 (Nov.)	1.0 (July)	48.0	67.3	47.5	57.4

Although an average of 70 per cent of the rainfall of each region is induced by two types of pressure conditions, four to eight types are discussed under each district. A total of nearly a score of rainfall types are considered. Weather maps illustrating the chief types are reproduced in profusion. (See figs. 9, 10.) The more important causes of widespread rain are western and eastern tropical LOWS, tropical trough, tropical tongue, tropical bulge, antarctic LOW, antarctic trough, central LOW, HIGH. Tropical LOWS bring most rainfall to northern Australia; antarctic LOWS bring most to Tasmania, to extreme southwestern, and to much of southeastern and east-central Australia. In central and east-central Australia tropical troughs are dominant as rain bringers, and they are second in importance in several districts elsewhere. Coastal cyclones, often developing into "willy-willies," are important in the northwest, as are Queensland hurricanes in the northeast.

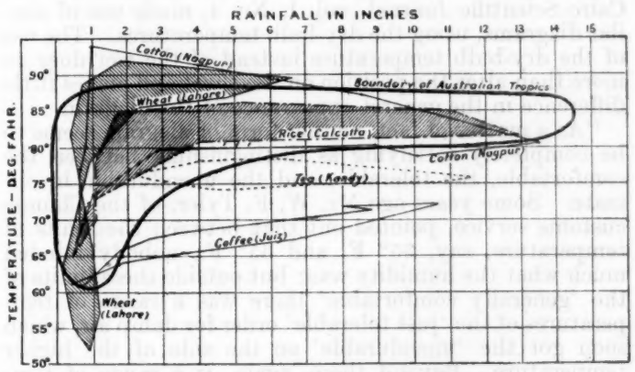
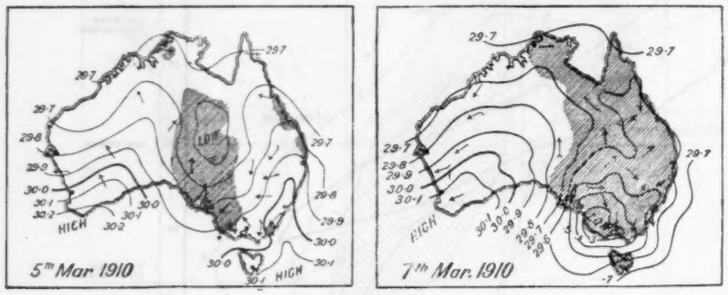


FIG. 8.—Hythergraphs for tropical areas growing wheat, rice, cotton, tea, and coffee. The heavy dark line shows the limit for most of our tropical localities.

The eastern coast also gets much rain from coastal LOWS which "surge down that coast" and from "southerly bursters which move up it." In the north "summer cyclones hover over the Territory for days" and yield

copious rain. At many points there a fall of more than 20 inches has been received within 24 hours, and several times falls in excess of 30 inches have occurred. An oval area 20 by 85 miles receives an annual average of more than 100 inches. One point (Harvey Creek) has a 19-year average of 163.7 inches.

This memoir with its 183 maps and diagrams and its 74 tables requires much more than the foregoing summary to be fully appreciated. It is an important piece of work well done. It would have been improved, however, by summaries, and index, and perhaps by the use of fuller base maps. No two of the larger maps of Australia are on the same scale, or on the same base; reference points and lines are quite inadequate on most



FIGS. 9, 10.—Australian weather maps: Tongue developing into cyclone, and cyclone forming at tip of tongue. (Rainfall indicated by shading.)

of these maps, and on the weather maps for intercomparison. Nevertheless, in each one the features shown are very clear.

CLIMOGRAPH CHARTS.[1]

By Sir NAPIER SHAW.

[Abstract.]

That the climographs, prepared by Dr. Griffith Taylor, which attempt to give graphically an idea of the climatic conditions of a locality by means of plotting relative humidity against the wet bulb temperature, are not the first attempt of this kind, is a fact that should be noted. Dr. John Ball, of the Egyptian survey department, in the Cairo Scientific Journal, vol. 1, No. 4, made use of similar diagrams, using the dry-bulb temperatures. The use of the dry-bulb temperature instead of the wet does no more than alter the position on the sheet and makes little difference in the general appearance of the diagram.

"As a matter of fact, neither form of diagram seems to be completely satisfying as distinguishing between the comfortable, the tolerable, and the unendurable in climate. Some years ago Mr. W. F. Tyler, of the Chinese customs service, pointed out that between the limits of temperature, say, 55° F. and 65° F., nobody minded much what the humidity was; but outside these limits of the 'generally comfortable' there was a range of temperatures of the 'just tolerable' order for damp air, which soon got the 'unendurable' on the side of the higher temperature. Beyond these, again, is a range of temperatures under which life is possible only in dry air. An effective climatic diagram would in some way or other exhibit the relation of the climate to the ranges compatible with comfort, life, and death."—*C. L. M.*

[1] *Nature*, London, Jan. 16, 1919, No. 2568, vol. 102, p. 383.

A NEW INTERPRETATION OF THE RELATIONSHIPS OF TEMPERATURE AND HUMIDITY TO INSECT DEVELOPMENT.[1]

By Dr. W. DWIGHT PIERCE, Bureau of Entomology.

[Abstract.]

"Upon the proper interpretation of the laws of climatic control of life rests the solution of many practical problems, and inasmuch as all plant and animal life reacts to climate in the same general manner it is apparent that

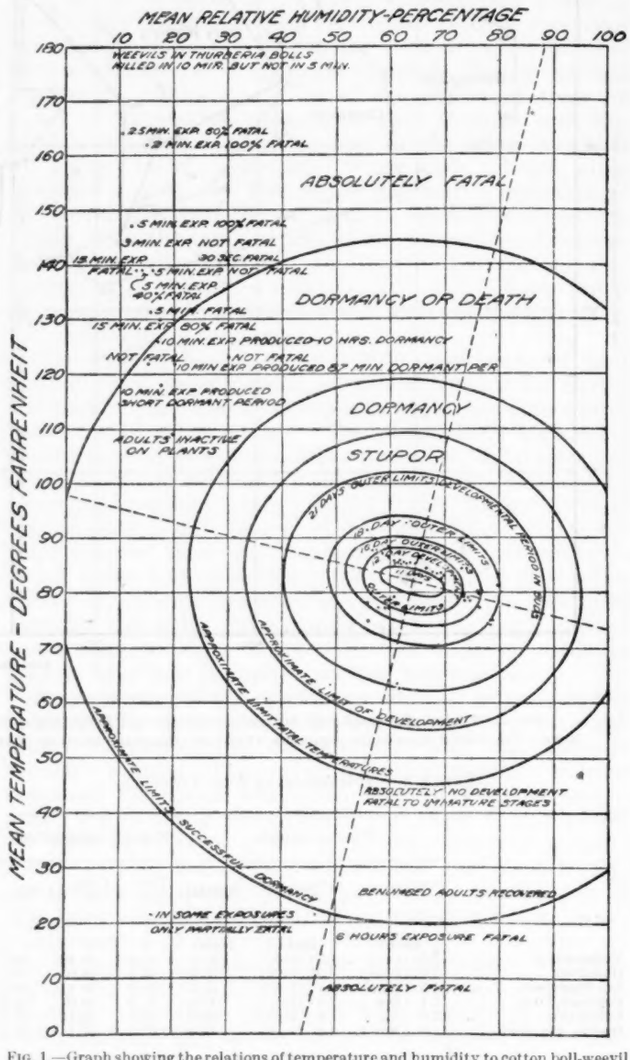

MEAN RELATIVE HUMIDITY-PERCENTAGE
10 20 30 40 50 60 70 80 90 100
MEAN TEMPERATURE - DEGREES FAHRENHEIT
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
WEEVILS IN THURBERIA BOLLS KILLED IN 10 MIN. BUT NOT IN 5 MIN.
2.5 MIN. EXP. 60% FATAL
2 MIN. EXP. 100% FATAL
ABSOLUTELY FATAL
5 MIN. EXP. 100% FATAL
3 MIN. EXP. NOT FATAL
30 SEC. FATAL
1.5 MIN. EXP. FATAL
1.5 MIN. EXP. NOT FATAL
5 MIN. EXP. 40% FATAL
1 MIN. FATAL
DORMANCY OR DEATH
15 MIN. EXP. 60% FATAL
10 MIN. EXP. PRODUCED 10 HRS. DORMANCY
NOT FATAL
10 MIN. EXP. NOT FATAL
10 MIN. EXP. PRODUCED 87 MIN. DORMANT PER.
10 MIN. EXP. PRODUCED SHORT DORMANT PERIOD
DORMANCY
ADULTS INACTIVE ON PLANTS
STUPOR
21 DAYS OUTER LIMITS DEVELOPMENTAL PERIOD IN FIELD
10 DAY "OUTER" LIMITS
5 DAY OUTER LIMITS
5 DAY LIMITS
APPROXIMATE LIMIT OF DEVELOPMENT
APPROXIMATE LIMIT MITIG. TEMPERATURES
ABSOLUTELY NO DEVELOPMENT FATAL TO IMMATURE STAGES
APPROXIMATE LIMITS SUCCESSFUL DORMANCY
BENUMBED ADULTS RECOVERED
IN SOME EXPOSURES ONLY PARTIALLY FATAL
6 HOURS EXPOSURE FATAL
ABSOLUTELY FATAL

FIG. 1.—Graph showing the relations of temperature and humidity to cotton boll-weevil activity.

the study of the climatic control of insect development may throw light upon the problems of all other forms of life."

Mr. Pierce thus opens his discussion of the relationship problem, and further notes that all so-called theoretical laws of effective temperature for all life do not properly explain many of the phenomena that are observed. The former theory of a fixed zero of effective temperature, so long maintained by biologists, is only in recent years rejected upon the findings that each species might have a different zero. In addition, it is only recently that the factor of humidity has been definitely used in the solution

[1] Jour. Agr. Research, Dept. of Agr., Washington, Mar. 20, 1916, pp. 1183-1191.

of the problem. Thus the effective zero has become the point at which metabolism begins for any type at a given relative humidity.

The greater mass of investigations, from which the earlier theories were derived, were made in north temperate regions where the effects of low temperatures were noted predominantly, and those of high temperatures comparatively little observed. The present studies were made by the writer of the paper and Mr. W. D. Hunter while in charge of a cotton boll-weevil force operating principally in Texas and Louisiana from 1902 to 1915. Thermohygrograph records of the free air were kept during the experiments, and artificial high and low temperature investigations were conducted, the former with "definite humidity control in order to determine the effects of heat" upon the boll-weevil. The diagram (fig. 1) expresses zone relationship found between temperature and humidity and the life activities of the insect from metabolism to death. A study of the cases of thousands of weevils taken individually disclosed their maximum efficiency to lie approximately at an average temperature of 83° F. and 65 per cent relative humidity. The temperatures and humidities at which dormancy and death ensue cover a wide range of absolute extremes.

The writer confesses to much difficulty in arriving at his first zero, since "only by a laborious series of testings can [it] * * * be approximated, unless the worker finds it by a fortunate chance." All the records of a given average humidity were tabulated together, and the zones of effective temperatures had to be arrived at individually for each moisture per cent.— *W. E. H.*

THE USE OF THE CLIMOGRAPH AS A TEST FOR WEATHER.

By M. M'CALLUM FAIRGRIEVE.[1]

(Author's Summary.)

Summing up these observations we may say that while the yearly climographs of a district or districts may resemble each other, the climographs from year to year, in Western Europe at all events, are widely different.

The very variability of the climograph may be one of the important and omitted factors of the question; the climograph in fact seems even more useful as a test of weather than as a test of climate. If a place or district has a very variable climate, its average climograph for a number of years may be of relatively small size, and may thus give the impression of a climate with but slight variations; its beneficial irregularities may not tell, while another place with but slight variations from normal will seem more comfortable than it is. And so, while welcoming the appearance of the climograph for the general average conditions as used by Dr. Taylor, it seems still more useful as a representation of the shorter period.

A typical climograph should not be based too much upon town readings; but one test of a natural region in this connection is the resemblance of climographs of individual stations in it.

Perhaps an instrument which continuously recorded for a month or year on a fixed sheet of paper the climograph coordinates, relative humidity and temperature, would be a useful variation of the climograph idea, as it would give the definite unaveraged facts for each station. Of course the resulting continuous curves drawn by the pen of the instrument would overlap; but the picture would give not only particulars of temperature and humidity, but also a good idea of their variabilty, i. e., it would give practically three sets of coordinates on one sheet of paper.

A word of warning may not be amiss that the average yearly conditions are not given by the centroid of the climograph as might be hastily assumed; the diagrams have no time coordinates, and points close together have not the effect of weighting the observations toward themselves. Thus in climographs for Scotland the points representing the winter months tend to come together about 40°, but the average looks as if it were very much higher.

[1] Jour. Scottish Meteorological Soc., 1916, vol. 17, pp. 148–155.

BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Brand, Walther.

Einige Ergebnisse der Registrierung von Luftdruck und Temperatur auf der Danmark-Expedition nach Nordostgrönland. Marburg. 1912. cover-title, 39 p. fold. chart. tables (part. fold.) 22½ cm. (Wissenschaftliche Beilage zum Jahresbericht der Oberrealschule . . . zu Marburg an der Lahn.) Progr.-Nr. 585.

Brockmöller, W.

Die geographische Verbreitung der monatlichen Barometerschwankungen. Kiel. 1912. 1 p. l., 43 p., 1. charts (part. fold.) tables. 30 cm. Inaug.-Diss.

Buresch, Hugo.

Bericht der meteorologischen Beobachtungsstation über den Zeitraum vom 1. Dezember 1908 bis 30. November 1910. (In Jahres-Bericht des k. k. Staats-Gymnasiums in Bielitz für das Schuljahr 1910/1911. Bielitz. 1911. p. [3]–7. tables. 23 cm.)

Dorsey, M. J.

Relation of weather to fruitfulness in the plum. Washington. 1919. cover-title. illus. plate. chart. tables. 26½ cm. (Reprinted from Journal of agricultural reserarch. Vol. 17, no. 3. p. 103–106.) "Literature cited," p. 125–126.

Ekholm, Nils.

Om perioder i väderleken och därpå grundade förutsägelser, särskilt med avseende på vintersjöfarten på Bottniska viken. Stockholm. 1919. cover-title. tables. 23 cm. (Särtryck ur Skeppstjänstkommitterades betänkande 2, p. 84–102.)

Hongkong. Observatory.

Report of the director for the year 1918. Hongkong. 1919. cover-title, 20 p. tables. 24½ cm.

Huntington, Ellsworth.

World-power and evolution. New Haven. 1919. 287 p. charts. 23½ cm. "References," p. [260]–265. [Points out influence of climate on evolution. Reviewed in *Science*, Aug. 30, 1919, pp. 211-213.]

Leffingwell, Ernest de K.

The Canning River region, northern Alaska. Washington. 1919. 251 p. plates. maps. diagrs. tables. 29 cm. 6 fold. maps in envelope at back. (U. S. Geological survey. Professional paper 109.) [Meteorology, p. 46–47; Climate, p. 60–62; Ground ice, p. 179–243, including a "Review of the literature on ground ice" and a "Bibliography."]

Mississippi. Geological survey.

Bulletin no. 14. Mississippi; its geology, geography, soil and mineral resources. A revision with additions of Bulletin no. 12. By E. N. Lowe. Jackson. 1919. 346 p. illus. fold. map. tables. 23½ cm. [Climate, p. 170–171; Weathering, p. 17–25; Soil erosion, p. 282–291.]

Oehmichen, Walter.

Über die Verwendbarkeit von Films zu Messungen der relativen Feuchtigkeit. Marburg. 1913. cover-title, 45 p. illus. fold. chart. tables. 22½ cm. Inaug.-Diss.

Ôsaka. Meteorological observatory.

Annual report for the year 1918. Part 2. Seismological observations in Ôsaka, 1918. Ôsaka. 1919. cover-title, 24 p. fold. charts. tables. 26 cm. Text in Japanese.

Rio Grande do Sul. Instituto astronomico e meteorologico da Escola de engenharia. Secção de meteorologia.

Dados meteorologicas, 1915–1916. Porte Alegre. 1917–1918. 2 v. charts. tables. 33 x 33 cm.

Royal aeronautical society.

A glossary of aeronautical terms. Prepared by the Technical terms committee of the Royal aeronautical society, approved by the Engineering standards association. Embodying a schedule of aerodynamical symbols approved by the Advisory committee for aeronautics. Edited for the Council by W. B. Faraday. London. 1919. 106 p. illus. 25 cm. ["Meteorology," p. 29–40.]

Skandinaviska geofysikermötet i Göteborg den 28–31 augusti, 1918.

Förhandlingar, utgivna av Otto Nordenskjöld och Hans Pettersson. [Göteborg. 1919.] xix, 79 [1] p. illus. charts. tables. 23½ cm. An "Index of papers read before the Congress" is given in English on p. [80].

Stolze, Hugo.

Untersuchungen über die hygroskopischen Eigenschaften der Kunstseide, der Kokonfäden und des Fischbeins. Marburg. 1914. cover-title, 36 p. tables. fold. diagr. 22½ cm. Inaug.-Diss.

Upsala. Université. Observatoire météorologique.

Bulletin mensuel. Vol. L. Année 1918. Upsala. 1918–1919. 1 p. l., 74 p. tables. 34 cm.

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

American philosophical society. Proceedings. Philadelphia. v. 58. no. 2. 1919.

Millikan, Robert A. Some scientific aspects of the meteorological work of the United States army. p. 133–149. [See Mo. WEATHER REV., Apr., 1919, p. 210–215.]

Physico-mathematical society of Japan. Proceedings. Tokyo. v. 1. June, 1919.

Torada, Torahiko. On the analogy of the temperature variation of Nova Aquila and the frequency variation of the after-shocks of earthquakes. p. 180–185.

Royal meteorological society. Quarterly journal. London. v. 45. July, 1919.

Hill, Leonard. Atmospheric conditions which affect health. p. 189–207.

Barnes, Alfred A. Rainfall in England: the true long-average as deduced from symmetry. p. 209–232.

Brooks, Charles E. P. The secular variation of rainfall. p. 233–248.

Mossman, R[obert] C. The mean temperature of Rio de Janeiro, 1871–1917. p. 249–251.

Brooks, C[harles] E. P. Charts of mean temperature in Africa. p. 251–252.

Captain Melville Willis Campbell Hepworth, R. N. R., C. B., R. D. p. 257–258. [Obituary.]

Lennon, Richard T. Unattended rain-gage. p. 266.

Royal society. Proceedings. London. ser. A. v. 95. no. A673. 1919.

Galitzin, B. An apparatus for the direct determination of accelerations. p. 492–507. [Of seismological interest.]

Galitzin, B. On the explosion at Okhta. p. 508–515. [Of seismological interest.]

Royal society. Proceedings. London. ser. A. v. 96. no. 674. 1919.

Richardson, Lewis F. Atmospheric stirring measured by precipitation. p. 9–18.

Richardson, Lewis F. Measurement of water in clouds. p. 19–31.

Science. New York. v. 50. 1919.

Romberg, Arnold. A practical long-period seismograph. p. 141–142. (Aug. 8.)

Ritter, Wm. E. Problems of population of the North Pacific area as dependent upon the biology, the oceanography and the meteorology of the area. p. 119–125. (Aug. 8.)

Brooks, Charles F. Organization of the American meteorological society. p. 180–181. (Aug. 22.)

Scientific American. New York. v. 121. August 2, 1919.

Dobbins, H. T. A tornado that tied itself in a knot. A remarkable loop formation luckily recorded by the camera. p. 114. [From MO. WEATHER REV., Apr., 1919, p. 234–236.]

Scientific American supplement. New York. v. 88. August 16, 1919.

Marshall, C. F. Dendy. Wind resistance and railway speeds. How the model of the engine front affects the train speed and power consumed. p. 105–106.

Kempe, H. R. Rainfall and horsepower. p. 110–111.

Scientific monthly. New York. v. 9. September, 1919.

Ward, Robert DeC[ourcy]. Some characteristics of the rainfall of the United States. p. 210–223.

Hinsdale, Guy. The sun, health and heliotherapy. p. 253–262.

Annales de géographie. Paris. 28 année. 15 juillet 1919.

Sorre, Max. L'atmosphère au-dessus de la Méditerranée, d'après les cartes du Meteorological Office. p. 315–317.

Astronomie. Paris. 33 année. Juin 1919.

Touchet, Em[ile]. A propos du phénomène des ombres volantes. p. 279–280.

France. Académie des sciences. Comptes rendus. Paris. Tome 169. 1919.

Rouch, J. La vitesse ascensionnelle des ballons-pilotes. p. 83–85. (15 juil.)

Maurain, Ch. Sur la vitesse du vent dans la haute atmosphère par temps clair. p. 79–82. (15 juil.)

Dunoyer, L., & Reboul, G. La prévision des variations barométriques. (Réponse à M. Gabriel Guilbert.) p. 78–79. (15 juil.)

Guilbert, Gabriel. Sur la prévision scientifique du temps par la prévision chiffrée des variations barométriques. p. 295–298. (11 août.)

Rouch, J. La variation diurne de la vitesse du vent dans l'atmosphère. p. 293–295.

Nature. Paris. 47 année. 19 juillet 1919.

Lefranc, Jean-Abel. La traversée aérienne de l'Atlantique. p. 40–46. [Includes discussion of meteorological features.]

Radium. Paris. 11 année. Mai 1919.

Wigand, A[lbert]. Mesures de conductibilité électrique dans l'atmosphère libre jusqu' à 9000 mètres d'altitude. p. 204–208.

Revue du ciel. Bourges. 4 année. Août 1919.

Moye, M. Paragrêles et niagaras électriques. p. 663–665.

Colin, Elie. Influence du soleil et de la lune sur le baromètre à Madagascar. p. 672–673.

Revue générale des sciences. Paris. 30 année. 15 juillet 1919.

Gain, Louis. La prévision des houles sur la côte du Maroc. p. 408–411.

Greece. Observatoire national d' Athènes. Athènes. Tome 7. 1916.

Éginitis D[emetrius.] Le trouble du ciel et l'affaiblissement du rayonnement solaire observés pendant l'année 1912. p. 7–12.

É[ginitis]D[emetrius]. Le tremblement de terre de Céphalonie-Zante du 24 janvier 1912. p. 19–22.

É[ginitis], D[emetrius]. Le tremblement de terre de Thèbes du 17 octobre 1914. p. 23–26.

É[ginitis], D[emetrius]. Les tremblements de terre de l'Eucade et d'Ithaque des 23 et 27 novembre 1914 et du 27 janvier 1915. p. 27–32.

É[ginitis], D[emetrius]. La pluie boueuse et la poussière rouge du 6 mai 1913. p. 33–34.

É[ginitis], D[emetrius]. Discussion générale des observations sismiques faites en Grèce pendant les années 1912–1914. p. 35–41.

Goulandris, E. Sur les tremblements de terre de Céphalonie-Zante du 24 janvier 1912. p. 42–46.

Goulandris, E. Sur le tremblement de terre de Thèbes du 17 octobre 1914. p. 47–50.

Critikos, N. L'île de Leucade et ses sismes du 23 et du 27 novembre 1914. p. 62–81.

Astronomische Nachrichten. Kiel. Band 208. 1919.

Meissner, Otto. Reduktion der Kirschen Temperaturbeobachtungen in Berlin. (1719–1751.)

Hemel en dampkring. Den Haag. 17 jaargang. 1919.

Everdingen, E. van. De halo van 24 Maart 1919. p. 10–14. (Mei.)

Pinkhof, M. Land- en zeewinden in Nederland. p. 17–20. (Juni.) [Continuation from Maart 1919. p. 172–174.]

Sociedad científica "Antonio Alzate". Memorias y revtsia. Mexico. Tomo 38. 1919.

Oropesa, Gabriel M. Las lluvias en la region de Necaxa. p. 249–255.

Società geografica italiana. Roma. v. 7. Maggio-Junio 1918.

Azzi, Gerolamo. Quadro fenologico della Bulgaria. p. 417–433.

SOLAR AND SKY RADIATION MEASUREMENTS DURING JULY, 1919.

By HERBERT H. KIMBALL, Professor of Meteorology, in charge.

[Dated Solar Radiation Investigations Section, Washington, Aug. 30, 1919.]

For a description of instrumental exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1919, **47**:4.

The monthly means and departures from normal in Table 1 show that the radiation measurements averaged below the July normal at Washington and Lincoln, and very close to normal at Madison and Santa Fe. At Madison a noon reading of 1.46 calories per square centimeter per minute, measured on the 10th, is the highest intensity ever measured at that station in July.

Table 3 shows a deficiency of 12 per cent for Washington and an excess of 7 per cent for Lincoln in the total radiation for the month as compared with the normal amounts for July. The total for Madison is close to normal.

The skylight polarization measurements made at Washington on 7 days give a mean of 46 per cent, with a maximum of 59 per cent on the 3d. At Madison, measurements made on 12 days give a mean of 56 per cent, with a maximum of 68 per cent on the 10th. These are average values for July.

TABLE 1.—*Solar radiation intensities during July, 1919.*

[Gram-calories per minute per square centimeter of normal surface.]

WASHINGTON, D. C.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
July 1			0.82		0.75	0.68				
2	1.11	1.10	1.00	0.92	0.82	0.75				
3	0.99	1.03	0.93	0.84	0.74	0.66	0.59			
5	1.01	0.87								
8	1.33	1.14	0.97	0.81						
11	1.27	1.15	0.88	0.79	0.71	0.64				
24	0.90	0.73	0.60							
25	1.07	0.91	0.61							
26	0.92		0.49							
28	**1.29**									
29	1.26									
30	1.22	1.04	0.89	0.78						
Monthly means	**1.12**	**1.00**	**0.80**	**0.83**	**0.76**	**0.68**	**(0.59)**			
Departure from 11-year normal	**−0.10**	**−0.09**	**−0.14**	**−0.05**	**−0.07**	**−0.05**	**−0.09**			
P. M.										
July 2		1.01	0.87		0.80	0.77				
3		0.66								
8		1.22	1.09	0.83	0.75	0.68				
11		1.10								
25		0.73	0.61	0.53	0.45	0.39	0.33	0.28	0.24	
29		1.13	1.00							
Monthly means		**0.98**	**0.89**	**(0.68)**	**0.67**	**0.61**	**(0.33)**	**(0.28)**	**(0.24)**	
Departure from 11-year normal		**−0.06**	**−0.10**	**−0.18**	**−0.11**	**−0.11**	**−0.34**			

TABLE 1.—*Solar radiation intensities during July, 1919*—Continued.

[Gram-calories per minute per square centimeter of normal surface.]

MADISON, WIS.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
July 1		0.79			0.44		0.33	0.29		
3		1.01		0.77	0.68					
7	1.35	1.24	1.12	1.04	0.97	0.89				
9		1.04	0.96	0.84						
10	1.47	1.31	1.20	1.14	1.07	0.99	0.92	0.86	0.82	0.78
11			0.99	0.87	0.77	0.69	0.67	0.62		
15	1.38	1.25	1.18	1.09	1.01					
16	1.43	1.31	1.21	1.13	1.06	0.99	0.94	0.88	0.84	0.80
17	1.37	1.25	1.12	1.04	0.98	0.92	0.86	0.81	0.77	0.74
18	1.15	0.92	0.73	0.61	0.50	0.42	0.37	0.33	0.31	0.29
19	1.14	0.97	0.85		0.71	0.66	0.59			0.40
20	1.11									
22	1.29	1.23	1.13	1.06	1.01	0.95	0.89	0.84		0.77
23	1.14	0.96	0.87	0.78	0.71	0.65	0.59		0.47	0.42
24	1.03									
25			0.70							
28					0.80					0.51
29	1.25									
30	1.02									
Monthly means	**1.24**	**1.11**	**1.00**	**0.94**	**0.82**	**0.80**	**0.68**	**0.66**	**0.64**	**0.59**
Departure from 10-year normal	**−0.01**	**±0.00**	**−0.01**	**−0.01**	**−0.06**	**−0.06**	**−0.09**	**−0.04**		
P. M.										
July 7		1.15	0.87							
10		1.32	1.22	1.13						
15		1.28	1.18	1.09	1.01					
16		1.23	1.12	1.00						
17		1.11	0.97	0.87						
18		0.88								
22		1.09	0.92							
29		0.97	0.85							
Monthly means		**1.13**	**1.02**	**1.02**	**(1.01)**					
Departure from 10-year normal		**+0.01**	**+0.05**	**+0.08**	**+0.10**					

TABLE 1.—**Lincoln, Nebr.**

A. M.										
July 2		1.06	0.91	0.82						
3		1.18	1.06	0.96	0.87	0.80				
9	1.34	1.22	1.11	1.02	0.93	0.85				
18		1.15	1.01	0.93	0.88					
22			1.13	0.99	0.95	0.87	0.78			
23		0.92	0.80	0.70	0.61					
24		1.00	0.88	0.76	0.68	0.60				
25					0.59	0.51				
26	1.30	1.18	1.07	0.99	0.91	0.85	0.79	0.74		
30	1.33	1.22	1.13	1.02						
Monthly means	**1.32**	**1.12**	**1.01**	**0.91**	**0.80**	**0.75**	**(0.78)**	**(0.74)**		
Departure from 5-year normal	**−0.02**	**−0.06**	**−0.07**	**−0.08**	**−0.09**	**−0.08**	**−0.03**	**−0.09**		
P. M.										
July 7		1.19	1.06	0.98	0.90	0.82	0.76	0.71		
9		1.20								
10		1.10	0.97	0.86	0.79	0.72	0.66	0.61		
11		1.11	1.02	0.94	0.87	0.80	0.73	0.67		
21		1.14	1.09	0.99	0.84	0.75	0.69	0.64		
22		1.01	0.88	0.74	0.58	0.47	0.40	0.30		
23		0.89	0.77	0.66	0.57	0.49	0.43			
24		0.96								
26		1.15	1.04	0.95	0.87	0.81	0.76			
Monthly means		**1.08**	**0.98**	**0.87**	**0.77**	**0.69**	**0.63**	**0.59**		
Departure from 5-year normal		**−0.09**	**−0.08**	**−0.09**	**−0.11**	**−0.11**	**−0.10**	**−0.04**		

TABLE 1.—*Solar radiation intensities during July, 1919*—Continued.

[Gram-calories per minute per square centimeter of normal surface.]

TABLE 1.—Sante Fe, N. Mex.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
July 7				1.17	1.10	1.02				
10	1.40	1.30			1.08	0.99				
11				1.06	1.01	0.94	0.88			
23	1.43									
26				1.11	1.05	0.99				
Monthly means	(1.42)	(1.30)		1.11	1.06	0.98	(0.88)			
Departures from 7-year normal	±0.00	±0.00		−0.04	−0.02	−0.04	−0.07			
P. M.										
July 22			1.16	1.08	1.04	1.01				
23		1.29	1.17	1.07	0.99	0.92				
24			1.14	1.07	0.97	0.93				
Monthly means		(1.29)	1.16	1.07	1.00	0.95				
Departure from 3-year normal		+0.01								

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Date.	8 a. m.	8 p. m.	Date.	8 a. m.	8 p. m.	Date.	8 a. m.	8 p. m.	Date.	8 a. m.	8 p. m.
1919.	mm.	mm.	1919.	mm.	mm.	1919.	mm.	mm.	1919.	mm.	mm
July 1	10.59	15.11	July 1	12.24	16.79	July 2	17.96	17.96	July 7	7.87	10.21
2	14.10	17.37	3	16.79	17.96	3	17.96	16.79	10	9.47	8.18
3	16.20	20.57	7	11.38	9.83	7	17.96	14.60	11	10.59	8.48
5	17.96	18.59	9	15.11	14.60	9	18.59	16.20	22	8.48	5.79
8	10.21	12.24	10	10.97	9.47	10	17.37	17.37	23	8.48	5.79
11	13.13	10.59	11	9.83	15.65	11	19.23	13.13	24	7.87	7.29
24	17.37	21.28	15	13.13	11.81	18	12.68	10.59	26	7.87	7.29
25	16.79	14.60	16	10.59	10.59	21	12.68	8.81			
26	16.20	21.28	17	11.81	10.97	22	9.83	8.18			
28	19.23	19.23	18	13.13	12.24	23	10.59	9.47			
29	19.23	12.24	19	14.10	11.81	24	9.83	11.38			
30	10.21	14.10	20	14.10	11.38	25	14.60	12.68			
			22	12.24	10.97	26	14.10	12.68			
			23	10.21	11.81	30	17.37	13.61			
			24	13.13	10.97						
			25	10.59	12.68						
			28	14.10	13.13						
			29	12.24	13.13						
			30	13.61	16.79						

TABLE 3.—*Daily totals and departures of solar and sky radiation during July, 1919.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
1	638	532	699	119	− 10	105	119	− 10	105
2	667	533	681	150	− 9	89	269	− 19	194
3	605	586	708	90	45	118	359	26	312
4	571	340	389	57	−201	−200	416	− 175	112
5	604	191	391	92	−349	−196	508	− 524	−84
6	430	651	702	− 80	112	116	428	− 412	32
7	365	690	707	−143	151	122	285	− 261	154
8	704	334	592	198	−204	7	483	− 465	161
9	466	251	695	− 38	−286	110	445	− 751	271
10	230	730	730	−272	194	146	173	− 557	417
11	685	648	609	186	113	25	359	− 444	442
12	561	638	627	64	104	43	423	− 340	485
13	353	350	640	−142	−183	57	281	− 523	542
14	393	342	489	−100	−190	− 94	181	− 713	448
15	212	681	551	−279	150	− 32	− 98	− 563	416
16	153	647	598	−337	119	16	− 435	− 444	432
17	241	661	479	−248	137	−101	− 683	− 307	331
18	202	602	670	−286	81	91	− 969	− 226	422
19	292	576	404	−195	59	− 173	−1,164	− 167	249
20	274	607	638	−212	93	62	−1,376	− 74	311
Decade departure.							−1,549	483	− 106

TABLE 3.—*Daily totals and departures of solar and sky radiation during July, 1919*—Continued.

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	Cals.	Cals.	Cals.	Cals.	Cals.	Cals.	Cals.	Cals.	Cals.
21	293	502	749	−192	− 8	175	−1,568	− 82	486
22	245	627	728	−239	120	156	−1,807	38	642
23	335	563	681	−148	60	111	−1,955	98	753
24	543	587	672	61	87	104	−1,894	185	857
25	641	464	638	160	− 32	72	−1,734	153	929
26	518	550	694	38	57	130	−1,696	210	1,059
27	625	504	652	145	14	90	−1,551	224	1,149
28	543	435	688	64	− 53	129	−1,487	171	1,278
29	571	491	672	92	6	115	−1,395	177	1,393
30	595	481	648	117	− 1	94	−1,278	176	1,487
31	178	220	292	−300	−259	−260	−1,578	− 83	1,227
Decade departure.							− 202	− 9	916
Excess or deficiency since first of year. gr.-cal.							−4,420	−4,949	−2,718
Excess or deficiency since first of year. per cent.							− 5.5	− 6.2	− 3.0

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE, MAY, 1919.

By C. G. ABBOT, Director.

[Dated Astrophysical Observatory, Smithsonian Institution, Washington, Sept. 2, 1919.]

In continuation of the publications begun in February, 1919, I give herewith the values of the solar constant of radiation obtained at Calama, Chile, for the month of May, 1919.

The table is in the usual form, and explanation of the symbols and arrangement of the table will be found by the reader in the MONTHLY WEATHER REVIEW for February, 1919.

Date.	Solar Constant.	Grade.	Transmission coefficient at 0.5 micron.	Humidity air mass 3.			Remarks.
				o/ρ_{so}	V. P.	Rel. hum.	
A. M.	cal.				cm.	%	
May 1	1.952	E−	0.872	0.653	0.16	20	
2	1.952	E−	.879	.637	.14	16	
3	1.893	VG+	.873	.636	.14	16	
4	1.958	E	.881	.680	.14	16	
5	1.954	E−	.878	.712	.11	13	Distant cirri in north.
6	1.955	E−	.872	.607	.12	14	Cirri in east, north, and west.
7	1.956	E	.875	.587	.11	13	Cirri scattered about sky moving northeast.
8	1.934	VG+	.886	.596	.14	14	Thin cirri scattered about sky.
9	1.924	VG+	.878	.596	.14	15	
10	1.937	E−	.870	.543	.17	20	
11	1.983	E−	.852	.482	.24	29	
12	1.924	E	.864	.456	.31	34	
13	1.901	G+	.862	.436	.33	43	
14	1.939	G	.853	.379	.38	46	Cirri in west.
15	1.895	E−	.873	.439	.24	28	Cirri scattered about east, south, and west.
16	1.884	VG−	.888	.518	.20	18	Cirri scattered over sky.
P. M.							
18	1.903	E−	.876	.532	.27	17	
A. M.							
19	1.927	VG+	.881	.506	.21	26	
20	1.936	VG+	.880	.531	.17	22	
21	1.931	VG+	.872	.578	.19	23	
22	1.943	VG+	.880	.594	.12	13	Cirri coming from southwest.
23	1.966	E−	.870	.587	.15	16	Thin cirri scattered about sky.
24	1.915	E−	.870	.582	.14	15	Some cirri in west.
28	1.940	VG+	.870	.734	.09	13	
P. M.							
29	1.931	VG+	.874	.664	.19	13	
A. M.							
30	1.975	E	.876	.718	.09	14	
31	1.956	E−	.870	.712	.07	12	

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL CONDITIONS.

By A. J. HENRY, Meteorologist.

In the Northern Hemisphere the greatest mean pressure for July is observed in the vicinity of the Azores and pressure is least in the Arctic regions and from India westward to the Persian Gulf.

The Azores HIGH in connection with the low pressure in the Arctic, exerts a powerful influence on wind and weather over a great portion of the Northern Hemisphere. Southwest winds prevail from the Rocky Mountains to western Europe and midsummer weather is best exemplified in this month.

NORTH PACIFIC OCEAN.

The oceanic high appeared to be farther north than usual at this season and in consequence there was less cloudiness and fog in the coast sections than is usual in July and foggy nights and mornings seldom occurred in the coast valleys. This feature was very detrimental to the growing bean crop, which is dependent upon the fogs for the necessary moisture to mature the crop.—*G. H. Willson.*

Pressure at Midway Island was continuously above normal after the first few days of the month, in contrast to the low pressure which prevailed there in June. At Dutch Harbor the month opened with pressure above normal. This continued until the 8th when a well-defined low-pressure area developed, lasting until the 12th. Thereafter conditions were about normal until the 27th when low pressure set in which continued to the end of the month. At Honolulu pressure was about normal, moderate fluctuations taking place at different times during the month.

An unusual amount of fog was encountered during the month by vessels using the northern route. Mr. Harold Ford, second officer on the British S. S. *Empress of Japan*, gives the following account of the experience of that vessel:

> You will observe that we encountered a very big fog bank through which we steamed four days at 15 knots, from longitude 158° east to longitude 168° west, between the parallels of 43° 34′ and 50° 22′ north, thence drizzling rain and light haze all the time, with low barometer throughout and low visibility, unpleasant, gloomy weather. Altogether very poor weather for the time of the year. You will notice quite a depression about 160° west, with a continuance of southwest winds and cloudy weather to arrival on coast.
>
> It was remarkable how clean cut was the eastern edge of the great fog bank in longitude 168° west. After passing through this longitude we had perfectly clear weather.

The *Empress of Japan* was in the fog belt from July 7 to 10. During this period, as already stated, pressure was below normal at Dutch Harbor.

Press reports indicate that a typhoon was developing in the Far East at the close of the month.—*F. G. Tingley.*

NORTH AMERICA.

By A. J. HENRY.

The current month: So far as available reports indicate, the outstanding features of the weather were the very irregular distribution of precipitation, the absence of decided warm spells, tropical cyclones, and severe local wind storms.

The drought of the previous months in northwestern United States has continued; on the southern boundary of the drought area, however, copious rains have fallen. The heavy precipitation in the Appalachians and over the lowlands to the eastward appears to have been due to a more or less local pressure distribution which caused a steady drift of southerly winds over the Carolinas and Georgia. The occurrence of such pressure distribution is seemingly fortuitous; in this case the winds were mostly from the ocean and heavy and continuous precipitation resulted. In the Plateau region and the far Northwest the pressure distribution was also at times for southerly winds, but these being from a warm, dry, continental interior, there was no precipitation to speak of.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The weather over the North Atlantic during July, 1919, was remarkable for the comparative lack of heavy winds, as all the marine reports received by the latter part of August fail to show any cyclonic disturbances covering extensive areas.

The mean pressure for the month was slightly lower than usual off the coast of Newfoundland, while it was practically normal on the coast of Nova Scotia and in the Gulf of Mexico. Slight positive departures were the rule along the American coast, while in the Bermudas and Azores the mean monthly pressure was about 0.1 inch above the normal, and on the coasts of Scotland and Ireland it was a little higher.

As shown in Chart X for July 3, the American steamship *Creole*, while in the Gulf of Mexico near latitude 27° 10′ N. and longitude 86° 36′ W. ran into a severe northwesterly gale. The observer reported as follows: "July 2 midnight, fresh northeast gale with violent rain squall and rough sea; July 3, 6 a. m., wind hauling around to northwest; moderating and clear sky by 10 a. m." The storm area was evidently of very limited extent, as a number of vessels not over 100 to 200 miles away from the *Creole*, experienced light to moderate winds, although heavy swells were reported at a considerable distance from the storm center.

On July 4 (Chart XI) the center of this storm was evidently near Pensacola, Fla., where a northerly gale of about 50 miles an hour prevailed, accompanied by rain, the barometer reading 29.50 inches. The storm area apparently did not extend into the Gulf, as vessels a comparatively short distance south of Pensacola reported light to moderate winds.

On the morning of the 14th (see Chart XVIII) the British steamship *War Bracken* encountered a strong northeasterly gale off the coast of Portugal and in the storm log the observer states: "Gale began on the 13th. Lowest barometer 30.15 inches; at 4 p. m. on the 13th at latitude 39° 44′ N., longitude 12° 20′ W. End of gale on the 15th, highest force of wind 55 miles an hour; no shifts of wind." While no reports were received from the immediate vicinity of the *War Bracken*, two vessels located between Madeira and Lisbon experienced moderate northerly and northeasterly winds with com-

paratively high barometric readings, while in the region to the northward winds of even less force prevailed.

The British dirigible *R-34*[1] left Scotland for America in the early morning of July 2, arriving at Mineola, N. Y., on the afternoon of the 6th. The return voyage was begun on the morning of the 10th, Norfolk, England, being reached on the morning of the 13th.

Charts IX to XIII show the atmospheric conditions over the ocean at Greenwich mean noon for each day during the air ship's westward journey, and Charts XIV to XVIII give the same information for the return voyage.

In the two 5° squares that include Halifax, Nova Scotia, and St. Johns, Newfoundland, fog was observed on 9 and 11 days, respectively, which is slightly below the normal for both localities. Fog was reported on from 1 to 2 days along the northern steamer lanes, and on 5 days off the north coast of Scotland.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

British Isles.—The greater part of July there was a constant proclivity for an extension northward of the anticyclonic system which is centered, in an ordinary July, over the Azores region. As a result the prevailing winds in this country were not merely of oceanic origin, but came from high latitudes, more often than not from the northward or northwestward, and in some few instances from the northeastward. The mean temperature of the month was consequently below the average, and especially so over eastern and central England * * *. In London (Camden Square) the mean temperature, 59.3° (F.), was 4.2° below the average and the lowest for July in the 62 years' record excepting 1879 (59.1°) and 1888 (58.9°). * * *

The general rainfall for England and Wales was 74 per cent of the average, for Scotland 36 per cent, and for Ireland 45 per cent of the average.—*Symons's Meteorological Mag., Aug., 1919, p. 81.*

France.—"Paris, August 17.—The thermometer has been hovering between 85° and 95° for the last week. A newspaper prints photographs showing various traffic centers of the city deserted at 2 p. m. Friday [the 15th].

"Reports from the Provinces say that the extremely warm weather is injuring the harvests. At Lyon the thermometer reached 120°.[?]"—*N. Y. Times, Aug. 18, 1919.*

Argentina.—Floods following a month of the heaviest rainfall ever recorded caused the loss of 1,100,000 cattle in the southern part of the Buenos Aires Province. In the northwest heavy snows are reported; in some places, it is stated, snow has reached a depth of 25 feet. Communication by railroad or telegraph is impossible in many sections.[1]

Chile.—Over 80 persons were killed and some 14 vessels of various sizes in the harbor were sunk during a terrific storm which swept over Valparaiso July 12 and 13. Property worth about $70,000,000 was destroyed.[1]

[1] See also p. 505 of this number of the REVIEW.

[1] The Pathfinder, Washington, D. C., Aug. 9, 1919.

DETAILS OF WEATHER OF THE MONTH IN THE UNITED STATES.

CYCLONES AND ANTICYCLONES.

There were more than the usual number of low and of high pressure areas during the month, but with minor exceptions these were of the usual summer intensity and did not call for the issue of storm warnings. During the month as shown by Chart III 11 primary low pressure areas were observed over the United States and southern Canada, and of these seven were of the Alberta type and these either passed eastward along the northern border and left the field of observation in the vicinity of the Gulf of St. Lawrence or else turned northward into Canada; two belonged to the South Pacific type and one to the Northern Rocky Mountain type and these passed east-northeastward across the Great Lakes into southern Canada; one was of the East Gulf type and it passed inland immediately east of Pensacola on the 4th and dissipated over Tennessee on the 5th. There were five secondary low-pressure area developments, one of these occurring over the middle Mississippi Valley on the 4th; three formed over the middle Atlantic States, one on the 6th, another on the 7th, and yet another on the 10th; and one formed over the Missouri Valley on the 30th. The number of lows exceeded the average number, 8.6, for the month of July.—*E. H. Bowie.*

The outstanding feature of the weather on the Pacific coast during the month of July was the persistence with which depressions formed over the plateau region. These depressions would form over the valley of the Colorado and the plateau of southern Nevada, slowly increase in energy and extend northward until they covered the entire plateau region, remaining in that section for a few days, and then, in most cases, would unite with a depression moving southeastward through British Columbia and Alberta and pass east, only to be followed within a few days by a recurrence of a similar depression. Several high areas appeared on the northern coast, but only on one or two occasions did they move inland, and then only with greatly diminished energy.—*G. H. Willson.*

Eleven high-pressure areas were charted (see Chart III), and of these five belonged to the Alberta type, three to the North Pacific type and three to the Northern Rocky Mountain type. All of these HIGHS except two moved eastward north of latitude 35° N. The two exceptions passed southward from the northern Rocky Mountain region and disappeared over Texas. The HIGHS of the month were not abnormal in any respect, but in number exceeded the average number for July for 21 years.—*E. H. Bowie.*

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Dated Weather Bureau, Washington, Sept. 1, 1919.]

PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds for July, 1919, are graphically shown on Chart VII, while the means at the several stations, with the departures from the normal, are shown on Tables I and III.

At the beginning of the month a strong high-pressure area that had moved from the Lake region during the closing days of June still persisted over the eastern third of the country. West of the Mississippi River pressure was somewhat lower, particularly in the Central Mountain and Plateau States, but without a distinctive storm center.

By the middle of the first decade the eastern HIGH had disappeared, and pressure remained low over practically all other districts. During the latter part of the decade high pressure again developed over the Great Lakes and moved eastward to New England, and there was a general rise in pressure over most parts of the country, although at the close sharp falls had occurred in the northeastern districts and pressure was falling in the South and far West.

During the second decade pressure was comparatively high off the Atlantic coast, and with more or less constancy this condition persisted during the greater part of the month, but no important anticyclones moved into or developed over the interior portion of the country during the last two decades, and the changes in pressure from day to day were mainly small.

The month as a whole was distinctly free from well-developed low areas, no single storm center of material importance extending over a wide area. The small tropical storm that approached western Florida from the Gulf on the morning of the 4th quickly dissipated on reaching the coast. (See page 500 and Chart XI.)

The pressure for the month showed no marked departure from the normal, the averages being uniformly slightly above normal from the Mississippi Valley eastward, and over the Southwest, and slightly below normal from the Missouri Valley westward, except over a small area in the far Northwest and the adjacent portions of British Columbia, where there was a small excess.

In the absence of any marked displacement of the pressure distribution usual to a midsummer month, the winds assumed the normal southerly course prevalent during the warmest periods of the year over nearly all districts from the Rocky Mountains eastward. In the mountain districts of the West variable winds, dependent mostly on the topography, prevailed, while along the Pacific coast the winds were, as usual, from the ocean toward the land, but they had a very general trend from the northwest.

TEMPERATURE.

The beginning of the month was marked by decidedly cool weather over most eastern districts, particularly along the south Atlantic coast, where, on the morning of the 1st, the lowest temperatures for the month were reported, and in a few localities the temperatures were the lowest ever observed in July. Likewise, in the far West temperatures were low for the season, but throughout the interior and northern portions of the country the weather was generally warm, and at a few points in the Great Lakes region the highest temperatures for the month were reported during the first few days.

As the month advanced there was a very general increase in temperature over the eastern districts, the maximum for the month occurring over large areas during this period. Temperatures were also higher for a few days in the more western districts, although near the middle of the first decade cooler weather set in over the northern Rocky Mountain States and gradually overspread the districts to the eastward, reaching New England about the 8th and 9th, at which time some of the lowest temperatures of the month were recorded.

The latter part of the first decade was mainly warm, except that cool weather was advancing into the upper Missouri Valley at the end, and during the following few days the lowest temperatures of the month were reported near the Great Lakes and locally to the eastward. At the same time warm weather prevailed throughout the middle section of the country from the Pacific coast eastward to the Great Plains, the highest temperatures of the month occurring very generally over the abovementioned region during this period. The heated area extended into the more eastern and southern districts by the middle of the second decade, when maximum temperatures of 100° or somewhat higher were reported locally in the Gulf and south Atlantic States.

No important temperature changes were noted during the middle and latter portion of the second decade, except about the 18th, when a decided fall was reported in the far Northwest due to an area of high barometer moving inland over the North Pacific coast. As this cool area advanced eastward during the close of the second and the early part of the third decade, some of the lowest temperatures of the month were observed over the central districts as far eastward as the Mississippi River.

The early part of the last decade of the month brought temperatures close to normal in nearly all parts of the country, except as noted above. With the advent of a low pressure area into the upper Missouri Valley about the 26th, there was a very general rise in temperature to the eastward and southward and during the following few days the highest temperatures of the month were observed at points in these regions. The latter part of the month was without important temperature changes and at the close near normal conditions prevailed in all districts.

Maximum temperatures of 100° or more were reported from practically all portions of the country, although extreme heat was not registered continuously over extended areas for any considerable period of time. In Florida the maximum temperature did not rise above 100°, while in the Dakotas and Montana extremes of 105° to 111° were recorded, and in the plateau region the highest reached ranged from 117° in Arizona to 110° and 111° in the plains of eastern Washington and southern Idaho.

Minimum temperatures were below freezing on several different dates during the month in the mountain districts of the West. Readings as much as 10° below freezing being reported at exposed points in Oregon and nearly 20° below freezing locally in the mountains of Montana. Over the great agricultural regions the lowest temperatures were generally between 40° and 50°, although at points in the Upper Lake region, northern New York, and interior New England they were occasionally below freezing.

The average temperature for the month was above normal over the greater part of the country, the excesses ranging generally from 2° to 5°. From Texas westward to Arizona the monthly averages were slightly below normal, and there were small areas in the southeastern States and along the North Pacific coast that had averages slightly less than normal.

PRECIPITATION.

Generally fair weather prevailed at the beginning of the month, and, save for general rains in the far Southwest, and local showers at widely scattered points elsewhere, there was little precipitation until the middle of the first decade, when considerable rain occurred from the middle Plains northeastward to the upper Lakes and in the east Gulf States, extending during the following few days to most of the country from the Mississippi River eastward. During the latter part of the first decade rains became general over the east Gulf States, and by the first of the second decade had again extended over much of the country from the Mississippi River eastward. This inaugurated a period of wet weather along the Atlantic and east Gulf coasts that continued almost without interruption until the early part of the last decade. During much of this period rain continued almost daily in the mountain regions of the far Southwest, but over many of the interior States the rainfall was scattered and frequently insufficient for crop needs, particularly in the far Northwest and over portions of the southern Plains States where severe drought persisted.

The latter part of the second and the early portion of the third decade brought heavy rains in portions of the west Gulf States, particularly in Texas, where the precipitation was frequently heavy. The middle and latter parts of the third decade were without material rainfall over the more eastern districts except in the Gulf States, where rains continued at frequent intervals until near the close. In the far Southwest the rains became less frequent during the last decade, although near the end another rainy period set in and some of the heaviest falls of the month occurred in the mountains of Colorado and New Mexico during this time. But little relief had come to the drought conditions in the middle Plains region at the close of the month, and similar conditions prevailed in the far Northwest. Much of the rain during the month was associated with thunder storms, although there appears to have been a rather marked absence of the more severe types of these storms.

For the month as a whole, rainfall was heavy and greatly above normal over the Atlantic coast districts from southern New England to Florida, in much of Texas, and generally in the far Southwest. There was a small excess in the upper Mississippi Valley and locally in the adjoining regions, but over the great interior valleys and west to the Pacific coast the rainfall was nearly everywhere deficient. For the State of Arizona as a whole the rainfall was the greatest of record and similar conditions prevailed, but to a less extent, in portions of New Mexico and Colorado. Heavy rains, approaching the intensity of cloudbursts, were of frequent occurrence and much damage resulted to bridges and roads on account of the high waters. In the Atlantic coast districts the period from about the 13th to the 23d, inclusive, was remarkable for the continued and heavy character of the rainfall, particularly in the eastern districts of the Carolinas, where the falls were in some cases recordbreaking, and the run-off caused much damage to crops in the lowlands.

The rainfall for the month presented many unusual features, particularly in its distribution over comparatively small areas. Despite the heavy rainfall so general in the eastern and southern districts, where monthly falls of 10 to 15 inches or more were common, small areas had

less than 2 inches, and, in some cases, less than 1 inch during the entire month. In Texas, Arizona, New Mexico and Colorado the variations were greater. In the portions of the country where rainfall was deficient local areas in all the States had good rains at some period. This was particularly noticeable in the West and far Northwest where local heavy falls afforded occasional relief from the general drought prevailing. In portions of the northern Plateau and Pacific coast States, the period from May to July, inclusive, of the present year has been the driest in the history of the respective localities. In California water for power and irrigation purposes is growing alarmingly low and much anxiety exists least the supply become exhausted before the rainy season sets in. (See p. 507, below.)

RELATIVE HUMIDITY.

The averages of the relative humidity for the 8 a. m. and 8 p. m. observations present some unusual features, particularly along the Atlantic and Gulf coasts, where, although rainfall and damp weather seemed to persist almost constantly, the average relative humidity was frequently below the normal and usually only slightly above. In portions of Arizona and surrounding States where rainfall was likewise heavy, but not more continuous, this element was far above normal.

The persistence of drought conditions in the central Plains and far Northwest is well illustrated in the marked decrease in the relative humidity for the month as compared with the normal, the negative departures at some points being the greatest ever known.

LOCAL STORMS.

Considering the rainy character of the month over the eastern and southern districts there was a marked absence of high winds, in fact the early part of the month was notable for the small amount of wind movement in portions of the middle Atlantic States.

At Williston, N. Dak., a severe wind and hail storm on the night of the 6th and 7th caused much damage to crops.

At Dubuque, Iowa, a severe rainstorm and freshet on the 9th caused the death by drowning of seven persons, and much loss to property resulted from the high waters. The rate at which rain fell during this storm was the greatest in the history of the city. (See pp. 468, 506 in this issue of the REVIEW.)

In Pennsylvania a series of severe storms occurred on the 10th. A severe storm occurred in the vicinity of Pittsburgh on that date, several persons being killed or injured and much damage done. At Bradford a tornado passed over the town, killing two persons and causing much damage to buildings and crops; and a damaging storm occurred at Wellsboro on the 22d, causing losses estimated at over $100,000.

A severe thunderstorm swept western Long Island and the neighboring mainland on the 30th destroying trees, buildings, hangars, and airplanes at Mineola and leveling several acres of large trees in the lee of the reservoir at Purchase, N. Y.

Average accumulated departures for July, 1919.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	In.	In.	In.	P. ct.		P. ct.	
New England	69.9	+1.3	+15.9	3.01	− .59	+ 0.91	5.5	+0.4	78	− 2
Middle Atlantic	75.1	+4.5	+18.7	6.40	+2.10	− 1.70	5.3	+0.4	74	+ 1
South Atlantic	78.8	+2.6	+ 7.7	7.71	+1.70	− 0.30	5.6	+0.8	80	+ 1
Florida Peninsula	81.5	−0.8	− 3.6	7.65	+1.30	+10.10	6.0	+1.0	77	− 1
East Gulf	79.9	−0.4	− 1.1	6.88	+1.60	+ 5.26	6.1	+0.7	81	+ 3
West Gulf	81.6	−4.4	− 9.4	3.47	0.00	+ 2.30	4.6	+0.3	76	+ 1
Ohio Valley and Tennessee	78.3	+1.7	+ 9.9	3.32	−0.70	− 2.20	4.3	−0.5	67	− 4
Lower Lakes	72.9	+1.2	+18.0	2.63	−0.80	− 1.30	3.8	−0.8	63	− 7
Upper Lakes	70.9	+2.7	+26.3	2.35	−0.60	− 2.10	3.8	−0.9	65	− 8
North Dakota	71.6	+2.5	+25.2	2.35	−0.60	− 1.35	3.8	−0.4	65	− 1
Upper Mississippi Valley	78.1	+2.4	+18.4	3.66	+0.20	− 0.20	3.3	−1.1	64	− 5
Missouri Valley	79.9	+3.3	+19.9	2.09	−1.70	− 2.70	2.9	−1.3	64	− 1
Northern slope	71.9	+3.8	+21.6	1.63	.00	− 3.00	3.7	0.0	47	− 9
Middle slope	79.2	+2.8	+ 6.7	1.88	−1.10	− 3.20	3.3	−0.8	59	− 2
Southern slope	78.4	−2.1	−12.5	1.72	−1.10	− 2.40	3.8	−0.4	66	+ 6
Southern Plateau	81.2	−0.2	− 6.2	1.40	+0.20	+ 0.60	3.4	0.0	50	+10
Middle Plateau	76.2	+3.4	+11.1	0.37	−0.20	− 2.40	2.2	−0.8	35	− 1
Northern Plateau	73.9	+3.0	+12.4	0.07	−0.40	− 2.90	2.2	−0.6	31	−12
North Pacific	61.5	+5.0	+ 8.4	0.16	−5.40	− 4.00	4.0	−0.6	61	−14
Middle Pacific	64.7	−4.7	− 5.4	0.00	0.00	− 2.00	2.9	0.0	59	− 2
South Pacific	71.4	+0.8	+ 5.2	0.00	0.00	− 3.80	1.8	−0.9	65	+ 1

Winds of 50 mis./hr. (22.4 m./sec.) or more during July, 1919.

Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.
Charleston, S. C.	14	51	ne.	New York, N. Y.	26	65	sw.
Columbus, Ohio	12	52	nw.	Do.	28	51	nw.
Dayton, Ohio	31	51	nw.	Norfolk, Va.	29	56	nw.
Jacksonville, Fla.	16	51	sw.	Pensacola, Fla.	4	58	ne.
Louisville, Ky.	15	54	sw.	Pittsburgh, Pa.	10	58	nw.
Do.	31	56	n.	Point Reyes Light, Calif.	11	50	nw.
Minneapolis, Minn.	13	50	nw.	Do.	12	55	nw.
Mobile, Ala.	7	57	n.	Do.	31	50	nw.
Mount Tamalpais, Calif.	5	56	nw.	St. Paul, Minn.	13	57	sw.
Do.	11	58	nw.	Williston, N. Dak.	6	64	n.
Do.	12	52	nw.	Do.	7	52	nw.
New York, N. Y.	22	50	s.				

SPECIAL FORECASTS AND WARNINGS. WEATHER AND CROPS.

WEATHER WARNINGS, JULY, 1919.

EDWARD H. BOWIE, Supervising Forecaster.

During the month of July there were no abnormal atmospheric phenomena to be handled by the forecasters, except for frequent occasions for the issue of fire weather warnings in the far Western and Northwestern States and the necessity for frequent forecasts of rains for the Eastern and Southern States.

WASHINGTON DISTRICT.

The forecaster was called on during the month to issue many forecasts of showers, rains, and thunderstorms in the Atlantic and east Gulf States, in which regions the month was unusually rainy. Few storm warnings were necessary. On the 3d storm warnings were issued for the east Gulf coast when a disturbance was developing over the Gulf of Mexico. This disturbance passed inland immediately east of Pensacola, Fla., on the 4th and moved northward and disappeared over Tennessee on the 5th.

FORECASTS FOR THE "R-34."

The visit of the British dirigible the *R-34* was the occasion for the issue of daily forecasts for that airship before, during, and after its visit to our country. The first call for meteorological information and forecasts was received from the commander of this airship when she was off Newfoundland, and it was by radio through the shore station at Cape Race. Immediately on receipt of this call information of the prevailing weather and winds along the American coast north of New York and forecasts of wind and weather for the succeeding 24 hours were sent twice each day by radio until the airship reached Long Island. Perhaps the most important information contained in these advices was sent when the airship was flying westward between Nova Scotia and Cape Cod and encountering head winds. The prediction was to the effect that the winds would change to the northeast. Unquestionably this change in wind was most timely and enabled the airship to reach its destination without the aid of assistance from torpedo boats. During all the time that the *R-34* was moored at the flying field on Long Island, advices three times each day concerning the probable wind and weather were supplied its commander. Its dramatic departure was made on urgent advices from the Weather Bureau to the effect that a storm was approaching rapidly from the Great Lakes, that the wind and weather conditions, then favorable for a homeward start, would continue but a few hours longer, and that to remain moored on the flying field would be at the risk of having the airship torn from its moorings and swept away by winds and squalls that would set in before the expiration of the night. This bulletin was sent as an urgent message at 9 p. m. of the 10th, and shortly after midnight the *R-34* started her homeward flight under exceptionally favorable wind and weather conditions.[1] The next morning a half gale was blowing on Long Island, and general atmospheric conditions were most dangerous for an unprotected airship.

WARNINGS FROM OTHER DISTRICTS.

Chicago, Ill., Forecast District.—No warnings were issued during the month.—*Chas. L. Mitchell.*

New Orleans, La., Forecast District.—On the 3d conditions became locally threatening during the passage of a Gulf disturbance toward the East Gulf coast, and northeast storm warnings were ordered for the Louisiana coast at 12:30 p. m. The influence of the storm was evident at the mouth of the river, but its course was too far to the east to cause more than fresh winds on the Louisiana coast.

Small craft warnings were displayed on the Texas coast on the 6th because of disturbed conditions over southern Texas.

A number of thunderstorms occurred in coast sections, but there were no general storms without warnings.—*R. A. Dyke.*

Denver Forecast District.—The feature of the month was the continuation of the drought in northwestern Colorado, northern Utah, and adjacent regions to the northward, while heavy rains were even more common than usual in northern New Mexico and northern Arizona, with washouts and serious delays to railroad traffic. The rainfall was almost invariably in the form of thunderstorms, which were well covered in the forecasts. Fire weather warnings were issued on the morning of the 5th for fresh to strong winds in western Utah and northwestern Colorado.—*Fred'k H. Brandenburg.*

San Francisco, Calif., District.—The high temperatures and deficient rainfall caused the forest areas to become exceedingly dry and favorable for forest fires and as a matter of fact, large and destructive fires raged over the northeastern portion of this district during the greater part of the month. Fire weather warnings were issued in Washington, Oregon, and Idaho on the 7th, 10th, 15th, 18th, 21st, and 23d; in Nevada and northern California on the 7th, 10th, and 24th; in Nevada on the 21st; and in southern California on the 7th and 18th. These warnings covered periods of from three to four days in advance and the results were very gratifying.

The following commendations were received:

Your forecasts so far have been very accurate and beneficial.—*State Forester, Washington.*

I want you to know that we have been very much pleased with the fire weather predictions so far. They have been very nearly correct so far and we are much pleased that they have been so helpful.—*Forest Supervisor, Medford, Oreg.*

No wind or frost warnings were issued and none were necessary.—*G. H. Willson.*

[1] A full account of the meteorological conditions accompanying this flight is being prepared for the August issue of the MONTHLY WEATHER REVIEW.

RIVERS AND FLOODS, JULY, 1919.

ALFRED J. HENRY, Meteorologist in Charge.

For the first time in several months precipitation was so heavy and continuous as to cause heavy run-off and consequently much flooding in the streams of the Atlantic Drainage south of the James River, including the Flint and Chattahoochie Rivers of Georgia.

The rains began quite generally over the Appalachian region on the 16th and continued uninterruptedly over some portions until the 26th. Fortunately they ended over the mountain districts of Virginia and western North Carolina on the 22nd, although heavy rains fell after that date on the lowlands of North Carolina, South Carolina, and Georgia.

The soil was moderatley dry except in the southern part of the region and the run-off was not particularly heavy until the rains had continued about four days.

While the rainfall was not uniformly heavy over the region as a whole, the light rains served to keep the streams at a "near" flood stage. Heavy rains—an inch or more in 24 hours—fell in some portions of the region on the 16th, 17th, 18th, 19th, 20th, 22d, and 23d, and it was to these local downpours that the floods were in the main due. The Roanoke, Tar, Neuse, and Cape Fear Rivers of North Carolina were 10 to 15 feet above flood stage at one or more gauging points, the highest stage of record being reached on the Tar River at Tarboro on the 27th. Record stages of 24.8 feet at Neuse, N. C., and 26.4 feet at Smithfield, N. C., on the Neuse River, were reached on the 24th. Agricultural interests in the lowlands of eastern North Carolina suffered heavy loss.

The floods in the rivers of South Carolina and Georgia were not quite so severe as in North Carolina, the excess above flood stage ranging from 2 to 9 feet.

Heavy local and general rains in the last part of June caused a flood in the upper Trinity River of Texas. This flood passed down the lower Trinity from July 1 to 7. The Guadalupe, Neches, and Colorado Rivers of Texas were in flood locally at various times during the month due to heavy rains. The lower Rio Grande was in flood from the 24th to the end of the month, also in New Mexico on the 16th.

In all other districts floods were local and unimportant except that a severe local flood occurred in the outskirts of Dubuque, Iowa, on the 9th, the particulars of which have been furnished by Mr. J. H. Spencer, official in charge of the Dubuque, Iowa, Weather Bureau Office. (See also p. 468 above.)

Union Park, a pleasure resort on the outskirts of the city, to the northwest, is a narrow valley only a few hundred feet wide in places with steep hills on either side. Running through the valley is a creek, which is practically dry except during wet periods. During the period of excessive rainfall on July 9 this creek became a raging torrent many feet deep, overflowing its bank and destroying park property of all kinds. A number of picnickers took shelter from the rain in a pavilion near the creek. The rising waters quickly flooded the building and finally swept it away, precipitating its occupants into the freshet. In spite of heroic deeds upon the part of the park employees and others, five persons were drowned here or elsewhere in the park. Property loss at Union Park is estimated at from $10,000 to $15,000.

Another tragedy occurred on Thirty-second Street, near Heims' brickyard. Mrs. George Kennicker and two small children attempted to cross the street and the woman and one child were swept by the torrent of water into the Bee Branch sewer and drowned. The other child was carried over the mouth of the sewer and escaped, but with serious injuries.

The damage to waterway streets and to many streets on the level below the bluffs was surprisingly great. Kaufmann Avenue was completely ruined and also West Locust Street between Jackson School and Mount St. Joseph College. Julien Avenue and Dodge Street were badly damaged. Much of the brick paving on Eighth Street for several blocks above Bluff was stripped off and thousands of brick carried down by the water to the business section of the city. The wood-block paving for several blocks on Couler Avenue above Eighteenth Street was carried away and the avenue over this area was a wreck after the storm. Some of the streets below Main, particularly from the Carr, Ryder & Adams Co. factory northward to the Brunswick-Balke-Collender Co. factory, were covered with water during the height of the storm; water in large areas was 2 to 3 feet deep. Hundreds of cellars were flooded and some were completely filled with water and mud, the water reaching to the first floor in many instances. These were only typical instances of the damage of the storm. Few sections of the city from Eagle Point and the Brunswick-Balke-Collender Co. factory on the north to Dodge Street and the lumber yards on the south—a distance of about 4 miles—escaped damage.

City officials estimate that the streets of the city were probably damaged to the extent of $75,000 to $100,000. This may be correct, because many thousands of dollars will be required to clean and repair the streets, while some are beyond repair and will have to be replaced. There are hundreds of individual losses relatively small. Counting damage to city streets and at Union Park and individual losses, a conservative estimate of total damage would be $100,000.

* * * * *

Quite general and heavy rains occurred over southwest Texas on the 19th, 20th, and 21st. Nearly 10 inches of rain fell in Austin in a little more than 3 hours, almost equaling the so-called cloudburst of April 22, 1915, when 31 lives were lost as a result of local overflows. While much damage was done to bridges and roadways, the success of a large forage crop in west Texas was assured.

A severe local flood due to a 24-hour rain of 10.89 inches, 9.10 inches of which fell in 6 hours, on the early morning of the 19th occurred at Gainesville, Tex., where the flood waters of Pecan Creek overspread a good part of the town. Beyond damage to streets, bridges, and the lower floors of buildings, there was no material loss. Crops in the field, however, suffered heavy loss, in some cases being entirely destroyed.

On the 22d a heavy local rain in Tioga County, Pa., caused a destructive overflow on Morris and Jackson Creeks running through the town of Wellsboro. Very much damage was done in the latter to roads, bridges, buildings, and public utilities. Crops were destroyed in the county and transportation was seriously interrupted.

Estimated loss by flood, July, 1919.

District.	Tangible property, bridges, etc.	Crops.		Live stock and other farm property.	Suspension of business.	Estimated value of warnings.
		Prospective.	Gathered.			
Richmond, Va.	6,309	.....	.....	.....	5,255	10,000
Raleigh, N. C.	250,000	3,000,000	60,000	.....	200,000	360,000
Columbia, S. C.	19,600	406,500	15,700	4,875	17,540	462,750
Charleston, S. C.	7,500	105,000	20,000	950	63,000	50,000
Atlanta, Ga.	[1]	.....	.....	.....	.....	.....
Macon, Ga.	[2]	.....	.....	.....	.....	.....
Houston, Tex.	40,000	10,000	10,000	.....	500	100,000
Dallas, Tex.	8,000	220,000	15,000	500	.....	40,000
Total.	331,409	3,741,500	120,000	6,325	286,295	1,022,750

[1] To be reported later. [2] Nominal.

TABLE I.—*Flood stages in the Atlantic drainage during month of July, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Pompton:	*Feet.*			*Feet.*	
Pompton Plains, N. J.	8	.....	.....	7.6	23
James:					
Richmond, Va.	10	21	23	12.1	22
Roanoke:					
Randolph, Va.	21	20	21	23.5	21
Weldon, N. C.	30	18	26	45.2	23
Dan:					
Danville, Va.	8	21	21	9.4	21
Clarksville, Va.	12	.....	.....	11.7	22
Tar:					
Rocky Mount, N. C.	9	21	27	15.5	24
Tarboro, N. C.	18	23	(1)	37.0	27
Greenville, N. C.	13	21	(1)	24.5	28
Fish-Creek:					
Enfield, N. C.	14	22	27	19.6	24
Neuse:					
Neuse, N. C.	14	9	11	15.7	10
Do.	14	17	27	24.8	24
Smithfield, N. C.	14	19	29	26.4	24
Cape Fear:					
Elizabethtown, N. C.	22	9	9	23.9	9
Do.	22	19	29	34.2	25
Fayetteville, N. C.	35	19	26	52.0	24
Haw:					
Moncure, N. C.	22	18	23	23.0	22
Peedee:					
Cheraw, S. C.	27	20	25	36.3	23
Lynches:					
Effingham, S. C.	14	26	31	16.0	29
Black:					
Kingstree, S. C.	12	26	30	12.4	27–28
Santee:					
Rimini, S. C.	12	(2)	4	14.2	3 30–1
Do.	12	11	14	12.8	12–13
Do.	12	19	(1)	23.3	26
Ferguson, S. C.	12	(2)	5	13.3	1–2
Do.	12	13	(1)	17.1	27
Catawba:					
Mount Holly, N. C.	15	20	20	17.0	20
Catawba, S. C.	11	20	23	20.8	23
Wateree:					
Camden, S. C.	24	20	25	33.0	21
Congaree:					
Columbia, S. C.	15	21	24	20.5	21
Broad:					
Blairs, S. C.	15	20	23	18.4	21
Saluda:					
Pelzer, S. C.	7	21	21	8.0	21
Chappells, S. C.	14	20	23	18.5	21
Edisto:					
Edisto, S. C.	6	23	(1)	7.8	26–28
Oconee:					
Milledgeville, Ga.	22	.....	.....	21.4	25
Dublin, Ga.	22	.....	.....	21.4	27
Ocmulgee:					
Macon, Ga.	18	.....	.....	16.5	25
Abbeville, Ga.	11	24	(1)	14.6	30

3 Continued into June. 2 Continued from June. 1 Continued into August.

TABLE II.—*Flood stages in the east Gulf drainage during the month of July, 1919,*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Flint:	*Feet.*			*Feet.*	
Woodbury, Ga.	10	.....	.....	9.2	25
Montezuma, Ga.	20	27	27	20.0	27
Albany, Ga.	20	28	(1)	24.1	31
Bainbridge, Ga.	25	.....	.....	23.5	31
Chattahoochee:					
Eufaula, Ala.	40	.....	.....	39.8	26
Alaga, Ala.	30	26	28	35.3	27

1 Continued into August.

TABLE III.—*Flood stages in the Mississippi drainage during July, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Walhonding:	*Feet.*			*Feet.*	
Walhonding, Ohio.	8	.....	.....	11.8	20
Kanawha:					
Glenville, W. Va.	22	17	17	24.0	17
Elk:					
Clay, W. Va.	18	.....	.....	19.7	16
Gassoway, W. Va.	24	.....	.....	23.9	16
Illinois:					
Beardstown, Ill.	12	(1)	8	12.7	3–5

1 Continued from June.

TABLE IV.—*Flood stages in the west Gulf drainage during July, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Trinity:	*Feet.*			*Feet.*	
Dallas, Tex.	25	20	26	36.5	23
Liberty, Tex.	25	(1)	7	27.0	3–4
Trinidad:					
Trinidad, Tex.	28	29	(2)	32.4	31
Sabine:					
Bon Wier, Tex.	20	(1)	.....	19.0	1
Neches:					
Rockland, Tex.	20	(1)	4	23.2	1
Colorado:					
Columbus, Tex.	28	24	26	31.6	25
Guadalupe:					
Gonzales, Tex.	22	24	25	28.8	24
Victoria, Tex.	16	(1)	3	22.4	1
Do.	16	23	29	23.5	28
Rio Grande:					
Rio Grande City, Tex.	15	24	(2)	22.6	28

1 Continued from June. 2 Continued into August.

WATER SHORTAGE IN THE LOWER VALLEY OF THE COLORADO, JULY, 1919.

By F. H. BRANDENBURG, Meteorologist.

[Dated Denver, Colo., Aug. 8, 1919.]

The persistence of drought on the upper drainage of the Grand and throughout the drainage of the Green has had a marked effect on the discharge of the Colorado River. The winter's snow covering, having been much below the normal, sustained high temperatures during the latter part of May left but little for the summer run-off. Absence of rainfall on the watershed for several months was naturally reflected in the run-off, so that the Colorado reached a very low stage much earlier than usual. The volume discharged has been inadequate for the needs of the Imperial Valley which requires about 20,000 second-feet. This amount is less than the volume discharged in midsummer if not augmented by rainfall in Arizona and the mountain districts where summer rains, although local in character, are generally frequent and occasionally heavy. In the Palo Verde Valley 32,000 acres are under cultivation, 22,000 acres being in cotton, which will need another irrigation before the end of August.

MEAN LAKE LEVELS DURING JULY, 1919.

By UNITED STATES LAKE SURVEY.

[Dated Detroit, Mich., Aug. 5, 1919.]

The following data are reported in the Notice to Mariners of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during July, 1919:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.58	581.34	573.45	247.75
Above or below—				
Mean stage of June, 1919	+ 0.13	− 0.16	− 0.32	− 0.20
Mean stage of July, 1918	+ 0.34	− 0.60	+ 0.86	+ 0.90
Average stage for July, last 10 years	+ 0.18	+ 0.45	+ 0.67	+ 0.96
Highest recorded July stage	− 1.24	− 2.24	− 0.96	− 0.97
Lowest recorded July stage	+ 1.10	+ 1.44	+ 1.99	+ 3.16
Average relation of the July level to—				
June level	.....	+ 0.1	− 0.1	− 0.1
August level	.....	± 0.0	+ 0.2	+ 0.3

1 Lake St. Clair's level: In July, 576.24 feet.

EFFECT OF WEATHER ON CROPS, JULY, 1919.

By J. WARREN SMITH, *Meteorologist in Charge.*

Farm work.—Comparatively dry weather prevailed during the first half of July, rainfall being of a local character and mostly in the form of showers, which made conditions favorable for outdoor work, and farming operations made good progress. There was likewise little interruption in central, northern, and western districts during the latter half of the month, but rainfall was frequent and often heavy in the East and Southeast, which caused much interruption; very little farm work was possible during much of this period in Southeastern localities.

Winter grains.—The weather was favorable for harvesting winter grains and this work progressed to the northern limits of the winter wheat belt early in the month, while good advance was made in the late northern and western districts as the month progressed. It was exceptionally favorable for drying grain in shock and also for thrashing, except in restricted localities, principally in the Atlantic coast States, where thrashing was delayed and considerable damage done to grain in shock by wet weather. The yield of winter wheat was disappointing, however, and far below expectations in many of the principal producing areas.

Spring grains.—The weather during July was generally unfavorable for spring wheat in practically the whole of the spring wheat area. Continued dry weather produced very harmful results in the western portion of the belt, while disease in the eastern portion, under the influence of warm, wet weather during the first half of the month, caused pronounced deterioration. Later the crop ripened too rapidly under the influence of moderately high temperature and dry weather. Oats and other spring grains showed some improvement during the month in the Northeast, but in many other sections the weather was unfavorable for these crops, particularly in the Northwest, where serious damage was done by drought.

Corn.—Under the influence of favorable temperatures and mostly sufficient soil moisture, corn made good growth in nearly all sections during the first half of the month. It was too dry the latter half, however, in many normally heavy producing areas and at the close of the month corn was suffering greatly for moisture, and considerable damage had been done to the crop, in some localities, particularly from the lower Ohio Valley northward, in portions of the lower Missouri Valley, and from the central Great Plains northwestward. The weather continued favorable for corn in the Atlantic coast States.

Cotton.—While cotton in the western portion of the belt was in generally poor condition at the beginning of the month, under the influence of higher temperatures and less rainfall it made fairly good progress during July in that area. In most eastern sections, however, there was inadequate sunshine and too much rain, which unfavorably affected the development of the crop. There were many complaints of too rank growth at the expense of fruit and the weather was favorable for insect activity; weevil did much damage, particularly in districts where rainfall was frequent and heavy.

Potatoes, truck, and fruit.—The latter part of the month was rather unfavorable, on the whole, for potatoes and truck crops. They were unfavorably affected by lack of moisture in the central portion of the country and also in the West and Northwest, and by excessive moisture in the Atlantic coast States and many Gulf districts. The weather was mostly favorable for fruit, although there was some local damage to citrus fruit in Florida by heavy rain.

NOTE.—There was published in the National Weather and Crop Bulletin, No. 19, series of 1919, a chart showing for the country east of the Rocky Mountains the percentage of years with 30 consecutive days or more without 0.25 inch of rainfall in 24 hours for the period from March to September, inclusive. This chart shows graphically the relative frequency of warm season droughts of this character in different sections of this area. The percentages increase, as a rule, to the westward, and in the more western portions of the Great Plains phenomena of this character are practically of yearly occurrence. In the Ohio, central Mississippi, and lower Missouri Valleys the percentages range from 40 to 50; they show a rapid increase from the eastern portion of the Great Plains to the westward. The lowest percentages appear in the interior of the Northeast and in the area extending northward from the central Appalachian Mountain districts, where there is experienced, on the average, droughts of this character only about one year in three.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, July, 1919.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	79.5	−0.5	Union Springs	102	15	2 stations	56	2†	6.64	+1.31	Bay Minette	13.60	Florence	1.54
Arizona	79.0	−0.6	Mohawk	117	24†	Long Valley R. S.	37	31	5.57	+2.51	Long Valley R. S.	13.21	Yuma	0.06
Arkansas	81.2	+1.2	2 stations	104	11†	2 stations	54	18	1.91	−1.82	Bergman	7.35	Morrilton	0.10
California	72.4	−1.6	Blythe	119	9	Portola	23	30	0.01	−0.03	Warner Springs	2.47	191 stations	0.00
Colorado	68.0	+2.4	Greeley	106	8†	3 stations	30	5†	2.99	+0.61	North Lake	10.07	Lay	0.15
Florida	80.9	−0.5	3 stations	100	8†	2 stations	61	1†	8.77	+1.81	St. Andrews	18.87	Okeechobee	3.12
Georgia	79.3	−0.5	Statesboro	103	14	Clayton	52	2	8.71	+2.90	Concord	18.14	Rome	1.72
Hawaii (June)	74.0	+1.1	Mahukona	97	1	Glenwood	48	1	2.67	−2.13	Luakaha (Upper)	14.56	9 stations	0.00
Idaho	70.1	+2.5	2 stations	111	9†	2 stations	23	18†	0.22	−0.52	Atlanta	1.92	10 stations	0.00
Illinois	78.7	+2.8	La Harpe	104	31	Joliet	48	11	1.93	−1.68	Macomb	6.67	Greenville	0.30
Indiana	77.7	+2.4	Greencastle	104	31	La Porte	38	11	1.94	−1.60	Kokomo	5.88	Columbus	0.18
Iowa	77.4	+3.3	2 stations	104	30†	Waverly	41	16	2.86	−1.10	Dubuque	7.82	Allison	0.39
Kansas	80.2	+2.0	4 stations	106	10†	Alton	48	22	1.83	−1.71	New Ulysses	6.17	Concordia	0.03
Kentucky	79.5	+2.8	Earlington	104	29	Junction City	50	1	2.10	−2.20	Franklin	4.67	Henderson	0.17
Louisiana	81.7	+0.0	Angola	106	16	2 stations	60	3†	6.10	−0.35	Jeanerette	12.41	Calhoun	0.43
Maryland-Delaware	75.6	+0.2	2 stations	105	4	Oakland, Md.	41	12	7.89	+3.44	Newark, Del.	15.06	Cumberland, Md.	5.26
Michigan	70.7	+2.4	Harrisville	103	3	Houghton Lake	26	11	2.39	−0.86	Omer	6.51	2 stations	0.52
Minnesota	71.7	+2.9	Wheaton	105	26	Grand Rapids	40	9	4.83	+1.08	Warroad	9.87	Grand Marais	1.02
Mississippi	81.1	+0.4	Columbus	102	30	2 stations	59	3†	3.72	−1.56	Woodville	15.11	Holly Springs	1.08
Missouri	80.0	+2.3	Caruthersville	105	4†	Louisiana	50	7	2.33	−1.37	Conception	8.52	2 stations	0.32
Montana	69.5	+3.9	Mildred	109	24	Bowen	15	18	0.67	−0.74	Biddle	3.24	4 stations	0.00
Nebraska	77.7	+3.1	2 stations	109	9	Gordon	41	21	2.55	−0.86	St. Paul	7.51	Tecumseh	0.10
Nevada	75.2	+2.7	Logandale	113	10	San Jacinto	35	19	0.28	−0.16	Searchlight	4.01	17 stations	0.00
New England	70.3	+1.2	4 stations	102	4†	Somerset, Vt.	31	7	3.51	−0.14	Norwalk, Conn.	6.58	St. Johnsbury, Vt.	0.96
New Jersey	73.5	−0.1	Burlington	103	4	Charlotteburg	43	12	8.39	+3.84	Boonton	14.14	Northfield	4.45
New Mexico	70.9	−0.8	2 stations	105	11†	Red River Canyon	33	7	3.34	+0.65	Harveys Upper Ranch.	11.94	Loving	0.01
New York	70.3	+0.4	do	104	4†	Gabriels	29	8	4.78	+0.76	Spier Falls	10.88	Cape Vincent	1.03
North Carolina	76.6	0.0	4 stations	101	6	Banners Elk	40	1	8.71	+3.05	Louisburg	16.05	Hot Springs	1.48
North Dakota	71.0	+3.5	do	105	17	Willow City	37	10	1.80	−0.81	Grand Rapids	6.10	Arnegard	0.16
Ohio	75.1	+1.5	Brilliant	106	20	3 stations	44	11	4.02	−0.02	Bangorville	9.89	Montpelier	0.27
Oklahoma	81.7	+0.9	Mutual	110	31	Kenton	52	22†	1.75	−1.20	Ardmore	6.80	Antlers	T.
Oregon	68.1	+2.2	Umatilla	112	15	Lapine	22	7	0.12	−0.43	Sisters	1.43	23 stations	0.00
Pennsylvania	72.6	+0.6	3 stations	104	4†	West Bingham	34	8	5.90	+1.58	West Chester	14.58	Saegerstown	1.70
Porto Rico														
South Carolina	79.3	−0.5	2 stations	103	4	Cheraw	51	1	8.86	+2.95	Saluda	16.52	Liberty	3.48
South Dakota	74.9	+3.9	Howell	111	26	McIntosh	40	4	2.87	+0.14	Wentworth	6.35	Lemmon	0.85
Tennessee	79.1	+1.7	Loudon	103	14†	Mountain City	40	1	2.64	−1.97	Copperhill	6.83	Kenton	0.94
Texas	80.9	−1.7	Vernon	107	29	Bowie	50	2	4.67	+1.95	Cuero	15.31	Buena Vista	T.
Utah	73.6	+3.3	St. George	109	9	Blacks Fork	25	8	0.78	−0.26	Widtsoe	3.41	2 stations	0.00
Virginia	76.0	+0.3	Quantico	104	4	Burkes Garden	41	1	6.81	+2.16	Callaville	17.41	Spiers Ferry	1.61
Washington	66.7	+0.5	Winthrop	110	...	Colfax	29	19	0.21	−0.60	Snoqualmie Pass	2.50	14 stations	0.00
West Virginia	74.3	+1.0	Wheeling	104	4	Piedmont	41	12	5.51	+0.92	Camden-on-Gauley	13.08	Lock 20, O. R.	1.96
Wisconsin	71.7	+2.6	3 stations	101	27†	2 stations	34	11†	4.31	+0.32	Rest Lake	10.74	Racine	1.63
Wyoming	69.7	+4.2	2 stations	105	17	Sheridan Creek	23	19	1.13	−0.11	Sundance	3.68	Hyattville	0.00

*For explanation of the following table and charts, see this REVIEW, Jan., 1919, pp. 52-53.

† Other dates also.

TABLE I.—*Climatological data for Weather Bureau Stations, July, 1919.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.									Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with .01 or more.	Total movement.	Prevailing direction.	Maximum velocity.						
																								Miles per hour.	Direction.	Date.				
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°*F*		° *F*	° *F*		° *F*	° *F*	° *F*	° *F*	%	*In.*	*In.*		*Miles*								*In.*	*In.*
New England.							**69.9**	**+ 1.3**										**78**	**3.01**	**− 5.9**									**0–10 5.5**		
Eastport	76	67	85	29.86	29.94	+ .01	60.1	+ 0.3	82	20	69	45	3	51	30	56	55	87	2.82	− 0.6	13	5,510	s.	24	e.	7	5	15	11	6.1	.....	.....
Greenville	1,070	6	.....	28.80	29.94	.....	66.6	.....	92	4	78	45	9	55	39	.....	.....	.....	5.82	.....	16	.....	.....	.....	.....	.....	14	5	12	.....	.....	.....
Portland, Me.	103	82	117	29.85	29.97	+ .02	69.4	+ 1.4	98	4	78	50	9	61	37	63	59	73	1.62	− 1.6	9	6,087	s.	28	nw.	29	12	9	10	4.9	.....	.....
Concord	288	70	79	29.68	29.98	+ .02	71.2	+ 2.1	97	4	82	46	9	60	36	.....	.....	.....	1.47	− 2.3	8	3,339	s.	19	nw.	29	15	10	6	4.0	.....	.....
Burlington	404	11	48	29.53	29.96	+ .02	69.6	+ 1.4	94	4	80	49	8	59	32	.....	.....	.....	1.47	− 2.3	9	7,956	s.	38	s.	10	12	11	8	4.7	.....	.....
Northfield	876	12	60	29.05	29.98	+ .04	66.5	− 0.1	92	4	79	42	8	54	41	62	58	76	1.54	− 2.2	10	4,711	s.	27	sw.	27	6	17	8	5.8	.....	.....
Boston	125	115	188	29.84	29.97	+ .01	74.0	+ 2.7	101	5	82	55	9	66	31	66	62	70	4.63	+ 1.3	10	6,697	sw.	28	e.	31	7	10	14	6.0	.....	.....
Nantucket	12	14	90	29.98	30.00	+ .02	68.8	+ 1.3	92	4	76	51	9	62	28	65	63	86	4.76	+ 2.1	11	10,605	sw.	37	sw.	23	8	12	11	6.1	.....	.....
Block Island	26	11	46	29.97	30.00	+ .03	69.4	+ 1.3	90	5	75	55	9	63	22	67	66	92	4.94	+ 1.6	13	10,097	sw.	35	sw.	10	9	10	12	6.1	.....	.....
Providence	160	215	251	29.82	29.99	+ .02	73.3	− 0.1	99	4	82	52	9	65	32	66	62	72	3.68	+ 0.2	11	7,758	nw.	36	nw.	11	8	11	12	6.0	.....	.....
Hartford	159	122	140	29.82	29.99	+ .02	73.6	+ 2.0	99	4	82	55	9	65	34	66	63	74	2.44	− 1.7	11	5,276	sw.	31	sw.	26	9	7	15	6.0	.....	.....
New Haven	106	74	153	29.89	30.00	+ .03	73.4	+ 1.5	98	4	81	55	9	66	34	66	63	73	3.75	− 1.0	13	6,082	sw.	32	sw.	26	11	10	10	5.2	.....	.....
Middle Atlantic States.							**75.1**	**+ 4.5**										**74**	**6.40**	**+ 2.1**									**5.3**		
Albany	97	102	115	29.87	29.97	+ .01	73.2	+ 1.2	99	5	83	54	12	64	36	66	62	70	4.34	+ 0.4	13	5,376	s.	30	s.	21	13	10	8	4.8	.....	.....
Binghamton	871	10	84	29.09	30.00	+ .03	71.0	+ 1.1	96	4	82	51	12	60	41	.....	.....	.....	3.55	0.0	10	3,473	ne.	28	sw.	10	10	10	11	5.2	.....	.....
New York	314	414	454	29.68	30.00	+ .02	74.0	+ 0.5	98	4	81	58	1	67	30	66	62	72	7.93	+ 3.4	14	11,004	s.	65	sw.	26	8	12	11	6.1	.....	.....
Harrisburg	374	94	104	29.62	30.01	+ .03	75.2	+ 0.7	101	5	84	54	12	66	33	66	62	68	6.83	+ 3.0	13	3,973	n.	34	nw.	10	9	8	14	5.5	.....	.....
Philadelphia	117	123	190	29.89	30.01	+ .03	77.2	+ 1.4	100	4	84	61	1	70	29	69	65	71	10.30	+ 6.0	15	6,610	s.	27	s.	21	10	8	13	5.7	.....	.....
Reading	325	81	98	29.67	30.01	.....	75.2	.....	100	5	84	54	12	66	34	67	62	69	5.21	+ 1.0	13	4,264	se.	26	nw.	10	10	6	15	6.0	.....	.....
Scranton	805	111	119	29.17	30.02	+ .04	72.4	+ 0.6	98	5	83	50	12	62	37	64	60	69	4.81	+ 1.0	13	4,635	nw.	34	w.	26	7	9	15	6.4	.....	.....
Atlantic City	52	37	48	29.96	30.01	+ .03	73.8	+ 1.3	99	3	80	56	1	68	31	68	66	80	5.30	+ 1.5	13	5,180	s.	23	ne.	7	15	4	12	4.7	.....	.....
Cape May	18	13	49	30.03	30.05	+ .07	74.4	+ 1.0	98	3	81	55	1	68	33	69	67	83	5.68	+ 1.9	13	5,313	s.	24	se.	21	14	4	13	4.8	.....	.....
Sandy Hook	22	10	57	29.99	30.01	.....	73.6	.....	98	4	80	59	1	67	29	68	65	79	5.79	.....	15	9,253	s.	42	s.	26	13	9	9	5.0	.....	.....
Trenton	190	159	183	29.80	30.00	.....	75.1	.....	101	5	84	56	1	67	34	68	64	72	10.41	+ 5.6	14	7,292	s.	42	w.	10	10	8	13	5.9	.....	.....
Baltimore	123	100	113	29.88	30.01	+ .03	78.0	+ 0.7	102	5	86	60	12	70	31	70	66	70	7.21	+ 2.4	10	4,514	s.	26	nw.	10	11	6	14	5.2	.....	.....
Washington	112	62	85	29.89	30.00	.00	77.2	+ 0.4	101	5	86	56	1	68	35	70	67	75	6.80	+ 2.2	12	3,653	s.	28	nw.	10	10	7	14	5.5	.....	.....
Lynchburg	681	153	188	29.30	30.03	+ .02	77.2	− 0.1	97	4	87	53	1	67	33	70	67	76	5.21	+ 1.2	14	4,370	w.	48	nw.	15	14	10	7	4.5	.....	.....
Norfolk	91	170	205	29.94	30.04	+ .04	77.8	− 0.6	94	3	86	58	1	70	28	71	69	78	7.21	+ 1.4	12	8,561	s.	56	nw.	29	14	7	10	4.8	.....	.....
Richmond	144	11	52	29.88	30.02	+ .01	77.6	− 1.6	96	3	87	54	1	68	33	71	69	79	9.92	+ 5.5	12	3,046	s.	26	sw.	31	7	10	14	6.3	.....	.....
Wytheville	2,293	49	55	27.72	30.02	+ .01	72.3	− 0.3	90	14	83	46	1	62	33	66	63	80	1.75	− 2.7	11	2,955	w.	30	w.	15	12	14	5	4.3	.....	.....
South Atlantic States.							**78.8**	**+ 2.6**										**80**	**7.71**	**+ 1.7**									**5.6**		
Asheville	2,255	70	84	27.77	30.04	+ .02	73.2	+ 1.5	91	14	83	51	1	63	32	67	64	80	3.88	− 1.0	13	4,132	se.	29	n.	6	10	15	6	5.1	.....	.....
Charlotte	773	153	161	29.22	30.03	+ .01	78.6	− 0.1	97	15	88	56	1	70	30	71	68	76	7.40	+ 1.9	14	3,148	sw.	22	nw.	15	3	18	10	6.7	.....	.....
Hatteras	11	12	50	30.04	30.05	+ .04	77.3	− 1.3	88	29	83	62	1	72	16	73	72	85	2.13	− 4.0	11	10,170	sw.	44	nw.	29	10	10	11	5.0	.....	.....
Raleigh	376	103	110	29.64	30.02	.00	77.8	− 0.6	95	4	87	53	1	69	29	71	69	80	10.26	+ 4.2	13	5,225	sw.	35	se.	16	9	12	10	5.5	.....	.....
Wilmington	78	81	91	29.98	30.06	+ .05	78.6	− 0.1	95	14	87	54	1	70	25	73	71	83	8.43	+ 1.5	14	5,497	sw.	36	ne.	14	13	9	9	4.7	.....	.....
Charleston	48	11	92	30.00	30.05	+ .02	80.6	− 0.7	97	29	87	64	1	75	23	75	73	79	8.53	+ 1.3	13	7,269	s.	51	ne.	14	10	14	7	5.3	.....	.....
Columbia, S. C.	351	41	57	29.67	30.05	+ .03	79.9	− 1.2	98	14	88	60	2	71	28	71	68	75	10.83	+ 4.8	15	4,162	s.	26	sw.	6	9	9	13	6.0	.....	.....
Augusta	180	62	77	29.84	30.02	.00	80.4	− 0.1	98	7	89	59	2	72	28	74	72	81	10.26	+ 5.0	14	3,474	s.	27	s.	16	6	10	15	6.6	.....	.....
Savannah	65	150	194	29.98	30.05	+ .02	80.4	− 0.1	97	30	88	66	2	73	27	74	73	84	9.04	+ 2.9	16	7,080	sw.	42	n.	14	7	14	10	5.9	.....	.....
Jacksonville	43	200	245	30.00	30.05	+ .02	81.0	+ 0.1	94	13	88	70	1	74	19	75	73	84	6.32	+ 0.1	18	8,458	sw.	51	sw.	16	10	15	6	4.8	.....	.....
Greenville, S. C.	1,013	113	122	28.96	30.03	.....	77.4	.....	95	14	85	60	1	70	26	70	68	76	4.84	.....	12	4,689	ne.	31	sw.	15	5	15	11	6.1	.....	.....
Florida Peninsula.							**81.5**	**− 0.8**										**77**	**7.65**	**+ 1.3**									**6.0**		
Key West	22	10	64	30.01	30.03	+ .01	82.6	− 1.1	89	4	88	70	25	77	14	76	74	75	5.25	+ 1.7	18	5,647	se.	44	se.	25	6	16	9	5.9	.....	.....
Miami	25	71	79	30.03	30.06	.....	80.8	− 1.1	89	12	86	71	21	75	15	76	73	76	5.90	− 1.3	19	5,161	e.	26	e.	25	10	11	10	5.7	.....	.....
Tampa	35	79	92	30.02	30.05	+ .01	81.0	− 0.2	94	15	89	67	29	73	23	74	72	81	11.80	+ 3.4	19	4,138	ne.	33	s.	29	3	17	11	6.5	.....	.....
East Gulf States.							**79.9**	**− 0.4**										**81**	**6.88**	**+ 1.6**									**6.1**		
Atlanta	1,174	190	216	28.84	30.05	+ .03	77.3	− 0.3	93	15	85	61	1	69	24	70	68	80	7.50	+ 2.8	18	6,439	se.	34	nw.	31	5	10	16	6.6	.....	.....
Macon	370	78	87	29.64	30.03	+ .01	79.2	− 0.5	97	15	88	59	2	71	27	72	70	81	12.88	+ 8.2	18	3,685	se.	28	nw.	15	5	12	14	6.5	.....	.....
Thomasville	273	49	58	29.74	30.03	.00	79.6	− 3.2	94	14	88	64	2	71	25	73	71	84	9.81	+ 4.5	21	2,906	sw.	22	e.	27	2	13	16	7.2	.....	.....
Pensacola	56	149	185	29.95	30.01	.00	80.0	− 1.4	93	7	85	70	4	75	18	75	73	82	7.74	+ 0.5	14	8,367	w.	58	ne.	4	5	12	14	6.3	.....	.....
Anniston	741	9	57	29.27	30.05	+ .03	78.0	+ 0.1	94	14	88	58	2	68	30	.....	.....	.....	3.53	− 1.2	16	3,193	se.	30	nw.	11	13	13	5	4.7	.....	.....
Birmingham	700	11	48	29.29	30.04	+ .03	79.0	− 2.5	93	11	88	65	2	70	25	71	69	80	5.53	+ 0.8	18	3,772	e.	30	s.	26	6	16	9	5.9	.....	.....
Mobile	57	125	161	29.95	30.01	.00	81.6	+ 1.1	95	7	89	69	10	74	25	74	72	80	6.94	− 0.1	11	5,624	sw.	57	n.	7	4	19	8	5.9	.....	.....
Montgomery	223	100	112	29.78	30.02	.00	80.5	+ 0.5	94	11	89	64	2	72	25	73	70	79	4.67	0.0	18	4,163	se.	31	s.	27	6	13	12	6.0	.....	.....
Corinth	469	6	.....	.....	.....	.....	81.4	.....	98	30	93	62	17	70	30	.....	.....	.....	1.78	.....	9	.....	s.	.....	.....	.....	8	23	4	.....	.....	.....
Jackson	304	5	.....	.....	.....	.....	82.0	.....	96	14	93	65	3	72	27	.....	.....	.....	3.55	.....	9	.....	sw.	.....	.....	.....	13	14	4	.....	.....	.....
Meridian	375	85	93	29.62	30.00	− .02	80.0	0.0	94	11	89	63	3	71	26	73	71	79	3.69	− 0.8	12	2,866	sw.	40	n.	11	6	17	8	5.7	.....	.....
Vicksburg	247	65	74	29.74	30.02	+ .02	80.8	+ 0.4	93	15	90	69	7	72	21	74	72	81	5.72	+ 1.3	10	3,662	sw.	35	nw.	10	5	20	6	5.6	.....	.....
New Orleans	51	76	84	29.96	30.01	+ .01	82.6	+ 1.3	95	7	90	70	12	75	21	76	74	81	7.62	+ 1.2	14	3,909	w.	28	se.	12	3	19	9	6.1	.....	.....
West Gulf States.							**81.6**	**− 4.4**										**76**	**3.47**	**0.0**									**4.6**		
Shreveport	249	77	93	29.75	30.01	+ .03	82.6	+ 0.5	97	10	92	70	23	74	24	74	70	73	0.70	− 3.0	9	3,618	s.	28	e.	9	20	5	6	3.6	.....	.....
Bentonville	1,393	11	44	28.67	30.00	+ .03	78.6	+ 0.1	96	11	90	59	18	67	29	.....	.....	.....	2.50	− 1.8	4	2,482	s.	14	e.	26	24	6	1	2.4	.....	.....
Fort Smith	457	79	94	29.51	29.97	.00	84.0	+ 3.0	101	11	95	66	18	73	26	73	68	64	0.24	− 3.6	3	4,133	e.	20	se.	2	20	8	3	3.3	.....	.....
Little Rock	357	139	147	29.63	30.00	+ .01	82.2	+ 1.6	98	11	91	66	8	73	24	72	68	66	2.36	− 1.6	8	4,576	e.	48	nw.	8	15	15	1	3.9	.....	.....
Brownsville	57	4	26	.....	.....	.....	83.5	.....	96	16	92	70	4	75	22	.....	.....	.....	6.79	.....	12	.....	se.	.....	.....	.....	.....	.....	.....	.....	.....	.....
Corpus Christi	20	69	77	29.97	29.99	+ .03	81.7	− 1.0	93	16	87	72	24	76	17	76	75	83	6.24	+ 4.6	9	7,775	se.	46	se.	6	11	7	13	5.8	.....	.....
Dallas	512	109	117	29.45	29.99	.....	82.6	.....	98	11	91	69	18	74	21	.....	.....	.....	3.30	.....	8	5,119	s.	42	ne.	22	17	9	5	3.8	.....	.....
Fort Worth	670	106	114	29.25	29.95	− .01	81.4	− 2.3	97	15	91	68	18	72	24	73	70	74	5.25	+ 2.2	7	5,803	s.	31	e.	22	18	8	5	3.7	.....	.....
Galveston	54	106	114	29.96	30.02	+ .04	82.0	− 1.0	96	16	87	69	22	77	23	76	74	79	3.73	− 0.2	10	5,247	s.	40	ne.	16	10	11	10	5.4	.....	.....
Houston	138	111	121	29.86	30.00	.....	82.4	− 0.6	97	16	90	69	12	75	26	.....	.....	.....	7.30	.....	12	3,698	se.	29	e.	16	9	13	9	5.4	.....	.....
Palestine	510	64	72	29.48	30.00	+ .03	81.3	− 1.1	97	15	90	66	26	73	25	74	72	80	1.50	− 1.5	11	3,556	s.	27	e.	26	12	14	5	4.6	.....	.....
Port Arthur	34	58	66	29.96	30.00	.....	81.2	.....	96	16	88	69	26	74	25	75	74	82	10.06	.....	16	4,601	s.	41	ne.	8	5	15	11	6.5	.....	.....
San Antonio	701	119	132	29.27	29.98	+ .03	80.7	− 1.7	97	16	89	68	26	72	23	73	71	82	7.88	+ 5.7	13	4,756	se.	38	se.	3	8	9	14	6.0	.....	.....
Taylor	582	55	63	29.41	30.02	+ .06	80.4	− 2.3	97	16	89	68	6	72	24	.....	.....	.....	4.27	+ 1.6	12	4,393	s.	28	se.	3	7	14	10	6.0	.....	.....

TABLE I.—*Climatological data for Weather Bureau Stations, July, 1919*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with .01 or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	° *F*		° *F*	° *F*		° *F*	° *F*		° *F*	° *F*	%	*In.*	*In.*		*Miles*									*0–10*	*In.*	*In.*
Ohio Valley and Tennessee.							**78.3**	**+ 1.7**											**67**	**3.32**	**− 0.7**									**4.3**		
Chattanooga	762	189	213	29.24	30.03	+ .01	79.0	+ 1.2	93	30	88	62	2	70	27		70	67	73	2.07	− 1.8	9	5,061	w.	38	s.	25	5	20	6	5.6		
Knoxville	996	102	111	28.99	30.02	.00	79.5	+ 3.3	95	14	90	62	2	70	28		70	66	71	3.09	− 1.1	10	3,559	sw.	25	n.	29	8	15	8	5.4		
Memphis	399	76	97	29.62	30.04	+ .04	82.1	+ 1.4	94	13	90	66	17	74	25		73	70	70	1.94	− 1.6	5	4,000	sw.	32	ne.	11	18	9	4	3.4		
Nashville	546	168	191	29.46	30.03	+ .02	80.6	+ 1.2	95	13	90	66	21	71	28		71	68	70	1.83	− 2.5	8	5,006	w.	42	nw.	31	16	14	1	3.4		
Lexington	989	198	230	28.99	30.03	+ .02	78.8	+ 2.2	94	14	88	61	17	69	26					2.28	− 2.2	8	7,636	sw.	48	s.	5	15	12	4	3.4		
Louisville	525	219	255	29.45	30.02	+ .02	80.3	+ 1.7	97	13	91	62	16	70	28		70	66	66	3.47	− 0.3	5	6,747	sw.	56	n.	31	20	9	2	2.8		
Evansville	431	139	175	29.55	30.01	+ .01	82.1	+ 2.8	99	30	92	61	16	72	27		71	66	61	1.32	− 2.5	3	6,135	sw.	42	sw.	5	11	19	1	3.7		
Indianapolis	822	194	230	29.14	30.00	+ .01	78.6	+ 2.4	96	30	89	58	11	68	29		68	62	60	0.97	− 3.2	7	7,121	sw.	40	nw.	9	18	12	1	3.3		
Terre Haute	575	96	129	29.38	29.99		79.6		98	12	91	57	16	68	31		69	64	62	1.70		4	5,450	sw.	40	n.	31	12	19	0	3.8		
Cincinnati	628	11	51	29.35	30.01	+ .01	77.0	+ 2.8	95	13	88	55	11	66	34		68	64	65	2.08	− 1.5	7	4,330	sw.	32	nw.	10	17	11	3	3.4		
Columbus	824	179	222	29.16	30.01	+ .01	76.5	+ 1.2	97	4	87	56	11	66	30		68	64	68	4.93	+ 1.3	11	6,885	sw.	52	nw.	12	14	1	6	4.3		
Dayton	899	181	216	29.04	29.97		77.0		96	4	88	54	11	66	29		67	62	64	4.20	+ 0.9	6	5,947	sw.	51	nw.	31	20	9	2	3.1		
Pittsburgh	842	353	410	29.12	30.00	.00	75.4	+ 0.8	96	4	85	55	11	66	31		66	60	62	6.20	+ 1.8	10	6,892	sw.	58	nw.	10	15	5	11	4.2		
Elkins	1,940	41	50	28.04	30.02	+ .01	70.5	0.0	91	4	82	46	12	59	39		64	62	81	8.75	+ 4.1	15	2,718	nw.	24	nw.	15	1	7	13	5.8		
Parkersburg	638	77	82	29.39	30.04	+ .03	77.2	+ 1.6	97	3	88	56	12	67	33		67	63	67	3.30	− 1.4	10	3,325	se.	27	nw.	12	13	8	10	4.9		
Lower Lake Region.							**72.9**	**+ 1.2**											**63**	**2.63**	**− 0.8**									**3.8**		
Buffalo	767	247	280	29.18	29.99	+ .02	70.4	+ 0.2	90	18	77	51	11	63	24		63	58	68	1.33	− 2.1	8	10,451	sw.	47	sw.	10	13	9	9	4.6		
Canton	448	10	61	29.48	29.95		69.1	− 1.4	90	4	79	46	8	59	31					3.10	− 0.1	11	6,813	sw.	39	sw.	27	20	6	5	3.1		
Oswego	335	76	91	29.61	29.97	+ .01	70.0	+ 0.4	90	4	78	52	11	62	24		63	59	70	2.66	− 0.6	7	5,993	s.	33	nw.	5	16	8	7	4.0		
Rochester	523	97	113	29.44	30.00	+ .03	72.2	+ 1.8	96	3	82	50	11	62	31		63	58	63	3.40	+ 0.3	9	5,585	sw.	30	w.	10	18	5	8	4.1		
Syracuse	597	97	113	29.37	30.01	+ .04	71.2	+ 0.4	93	5	81	50	11	62	29					5.44	+ 1.8	11	7,121	s.	40	w.	10	13	11	7	4.6		
Erie	714	130	166	29.24	29.99	+ .01	72.8	+ 1.0	91	3	81	55	12	65	24		64	59	64	2.18	− 1.0	8	8,177	ne.	46	w.	10	12	14	5	4.3		
Cleveland	762	190	201	29.20	30.00	+ .01	73.2	+ 0.7	91	27	80	58	11	66	23		65	59	61	2.46	− 1.1	9	7,910	ne.	36	ne.	15	16	10	5	4.0		
Sandusky	629	62	103	29.33	30.00	+ .01	75.6	+ 2.0	96	5	84	59	11	68	31					2.23	− 1.6	7	7,470	ne.	42	nw.	9	15	10	6	3.9		
Toledo	628	208	243	29.33	30.00	+ .01	75.8	+ 2.1	95	5	85	52	11	66	30		66	60	61	1.40	− 1.8	6	8,663	sw.	47	nw.	9	20	8	3	2.9		
Fort Wayne	856	113	124	29.10	30.01		76.6	+ 3.1	94	4	88	52	11	65	32		65	59	58	2.68		6	5,542	sw.	31	w.	13	18	10	3	3.2		
Detroit	730	218	245	29.23	30.00	+ .02	75.0	+ 3.0	94	26	85	52	11	65	28		64	58	60	2.09	− 1.4	9	7,526	e.	40	sw.	9	17	11	3	3.4		
Upper Lake Region.							**70.9**	**+ 2.7**											**65**	**2.35**	**− 0.6**									**3.8**		
Alpena	609	13	92	29.34	30.00	+ .03	68.1	+ 2.3	95	3	78	45	11	58	34		62	58	70	2.13	− 0.9	8	6,979	sw.	39	nw.	27	14	10	7	4.1		
Escanaba	612	54	60	29.33	29.99	+ .02	68.6	+ 2.1	88	20	78	47	11	60	30		62	58	71	1.78	− 1.6	9	6,695	s.	32	s.	25	20	8	3	2.7		
Grand Haven	632	54	89	29.32	29.99	+ .01	71.8	+ 2.1	92	19	81	49	11	62	27		64	59	65	1.39	− 1.2	7	7,079	w.	37	w.	27	20	7	4	3.2		
Grand Rapids	707	70	87	29.25	30.00	+ .02	75.7	+ 3.1	97	2	87	50	11	64	31		64	57	55	0.66	− 2.0	8	3,900	nw.	23	nw.	9	15	9	7	4.3		
Houghton	684	62	99	29.24	29.95	− .01	68.5	+ 3.2	93	1	78	52	10	59	29					3.14	0.0	7	7,075	e.	37	w.	9	16	9	6	4.1		
Lansing	878	11	62	29.07	29.99		72.4	+ 1.3	95	26	86	42	11	59	36		64	59	68	1.69	− 1.5	11	3,292	sw.	26	nw.	9	16	10	5	3.7		
Ludington	637	60	66	29.31	30.00		68.6		85	19	77	50	11	61	23		62	58	68	2.45		12	6,470	s.	44	w.	9	15	11	5	3.6		
Marquette	734	77	111	29.21	30.00	+ .04	68.4	+ 3.5	94	26	78	50	7	59	34		61	57	67	2.47	− 0.6	6	6,876	nw.	41	s.	23	11	15	5	4.8		
Port Huron	638	70	120	29.31	30.00	+ .02	71.1	+ 0.1	96	3	81	46	11	61	31		63	59	66	1.71	− 1.0	8	6,619	ne.	48	nw.	9	17	10	4	3.6		
Saginaw	641	48	82	29.31	30.00		72.6		96	2	86	45	11	60	34		63	58	63	2.18	− 1.5	9	5,881	sw.	40	nw.	9	16	11	4	3.5		
Sault Sainte Marie	614	11	52	29.30	29.99	+ .02	66.7	+ 4.8	92	2	79	46	16	55	39		61	58	77	0.52	− 2.2	4	4,910	nw.	33	nw.	10	15	13	3	3.8		
Chicago	823	140	310	29.14	30.00	+ .02	77.0	+ 4.6	96	27	84	62	11	70	24		67	62	62	1.59	− 2.0	4	7,997	n.	46	w.	9	19	9	3	2.8		
Green Bay	617	109	144	29.32	29.98	+ .01	72.0	+ 2.5	94	26	82	52	11	62	31		64	60	67	5.39	+ 1.9	9	7,345	s.	49	nw.	27	16	8	7	4.7		
Milwaukee	681	119	133	29.26	29.99	+ .02	74.0	+ 4.3	97	27	82	59	11	66	31		66	61	68	4.00	+ 1.0	8	6,890	sw.	30	sw.	23	20	7	4	3.0		
Duluth	1,133	11	47	28.76	29.96	+ .01	67.1	+ 1.1	88	22	76	50	7	58	30		62	58	74	2.62	− 1.0	12	7,985	ne.	42	w.	9	11	12	8	5.0		
North Dakota.							**71.6**	**+ 2.5**											**65**	**2.35**	**− 0.6**									**3.8**		
Moorhead	940	8	57	28.95	29.94	.00	72.0	+ 3.3	99	26	84	50	10	60	35		65	61	74	5.56	+ 1.8	8	5,742	se.	36	se.	7	21	8	2	2.2		
Bismarck	1,674	8	57	28.19	29.93	.00	73.3	+ 3.1	100	17	87	47	19	60	44		61	53	54	0.76	− 1.4	5	7,349	se.	42	se.	6	11	18	2	4.3		
Devils Lake	1,482	11	44	28.37	29.91	− .02	70.0	+ 1.9	95	25	83	48	10	57	36		61	56	66	1.76	− 2.0	8	6,540	se.	33	ne.	26	15	10	6	4.1		
Ellendale	1,475	10	56	28.40	29.94		69.7		97	26	82	49	12	57	36		64	61	77	4.17		9	8,699	s.	46	s.	1	10	15	6	4.9		
Grand Forks	835	12	89				69.6		91	2	82	47	10	57	37		64			4.16		5			30	se.	1	20	7	4			
Williston	1,872	41	48	27.95	29.88	− .04	71.0	+ 1.6	101	17	84	51	21	58	43		58	50	52	1.33	− 0.7	5	5,965	n.	64	w.	6	18	11	2	3.4		
Upper Mississippi Valley.							**78.1**	**+ 2.4**											**64**	**3.66**	**+ .02**									**3.3**		
Minneapolis	918	10	208	28.96	29.92		74.6		96	25	84	56	12	65	23					6.19	+ 2.4	12	7,906	se.	50	nw.	13	13	10	8	4.7		
St. Paul	837	201	236	29.07	29.96	+ .01	73.6	+ 1.5	94	26	83	56	12	64	26					7.47	+ 4.1	11	7,974	se.	57	sw.	13	14	14	3	4.1		
La Crosse	714	11	48	29.22	29.97	+ .01	74.8	+ 2.2	98	30	86	55	11	64	30					2.55	− 1.5	11	2,933	s.	16	s.	26	14	11	6	4.3		
Madison	974	70	78	29.08	30.00	+ .03	74.8	+ 2.4	95	26	84	55	11	65	27	65	61	66		3.96	0.0	10	5,652	sw.	39	ne.	30	13	11	7	4.8		
Wausau	1,247	4		28.68	29.98		69.5		94	26	80	47	11	58	33					6.99		10		se.				17	6	8	3.8		
Charles City	1,015	10	49	28.93	29.98	+ .02	75.4	+ 1.9	98	30	87	54	11	64	33	67	62	66		4.47	+ 0.9	8	4,277	se.	23	sw.	13	19	12	0	3.2		
Davenport	606	71	79	29.34	29.99	+ .02	79.2	+ 3.8	96	27	90	61	7	69	26	68	63	62		2.56	− 1.0	7	4,602	sw.	35	ne.	9	22	7	2	2.5		
Des Moines	861	84	97	29.08	29.97	+ .01	79.8	+ 4.3	98	27	91	59	22	69	29	68	63	62		2.68	− 1.2	9	5,138	sw.	32	sw.	26	19	11	1	3.4		
Dubuque	698	81	96	29.26	30.00	+ .03	76.6	+ 1.9	95	27	87	56	11	67	27	68	63	67		7.82	+ 3.5	7	3,848	s.	24	n.	27	17	11	3	3.6		
Keokuk	614	64	78	29.33	30.00	+ .02	81.0	+ 4.0	100	31	92	62	7	70	30	70	64	61		2.47	− 1.6	7	4,632	s.	34	nw.	9	21	10	0	2.5		
Cairo	356	87	93	29.62	29.99	+ .01	81.4	+ 2.8	95	30	91	65	17	72	25	72	69	70		1.51	− 1.9	3	4,422	n.	47	nw.	11	15	11	5	4.1		
Peoria	609	11	45	29.35	30.01	+ .03	78.4	+ 3.0	98	28	90	57	23	66	34	69	64	69		3.09	+ 0.1	6	3,599	s.	22	n.	28	22	8	1	2.2		
Springfield, Ill	644	10	91	29.32	29.98	.00	79.8	+ 3.3	100	31	91	61	7	69	32	69	64	64		1.25	− 1.6	7	4,814	sw.	40	nw.	9	20	10	1	2.8		
Hannibal	534	74	109	29.43	29.99	+ .01	79.4	+ 2.0	98	31	91	59	18	68	33					3.73	0.0	7	5,171	sw.	37	w.	28	24	6	1	1.9		
St. Louis	567	265	303	29.40	29.99	.00	81.6	− 2.5	99	31	91	66	7	72	27	69	63	57		1.50	− 1.9	8	7,362	sw.	38	nw.	11	22	8	1	2.2		
Missouri Valley.							**79.9**	**+ 3.3**											**64**	**2.09**	**− 1.7**									**2.9**		
Columbia, Mo	781	11	84	29.18	29.99	+ .01	78.9	+ 1.5	97	31	90	59	23	68	31					2.52	− 1.1	6	3,998	s.	31	n.	11	23	7	1	2.2		
Kansas City	963	161	181	28.96	29.96	− .01	81.8	+ 4.2	98	31	91	66	22	72	25	69	64	59		1.14	− 3.7	5	6,829	s.	46	nw.	31	24	6	1	2.2		
St. Joseph	967	11	49	28.95	29.95		81.1		100	31	92	61	24	70	35	70	65	64		2.68		4	4,909	s.	33	nw.	5	25	6	0	1.8		
Springfield, Mo	1,324	98	104	28.64	30.01	+ .03	78.6	+ 2.2	94	11	88	63	18	69	25	69	64	68		1.96	− 2.8	6	5,651	se.	26	nw.	14	21	10	0	2.0		
Iola	984	11	50	28.96	29.97	.00	80.6	+ 2.5	101	11	93	58	23	69	36					2.21	− 1.7	3	3,777	s.	18	n.	4	23	8	0	2.4		
Topeka	983	92	107				81.6	+ 4.0	102	11	93	62	22	70	31					0.48	− 4.4	3	6,661	sw.	45	nw.	31	24	7	0	2.1		
Drexel	1,299	10	54	28.56	29.90		79.8		101	26	91	58	22	68	34	69	65	66		0.69		6	7,445	s.	31	s.	26	21	7	3	2.6		
Lincoln	1,189	11	84	28.69	29.92	− .03	82.2	+ 5.8	103	26	94	57	22	71	35	69	63	59		0.38	− 3.4	4	7,037	s.	29	s.	26	21	7	3	3.0		
Omaha	1,105	115	122	28.79	29.94	− .01	81.8	+ 5.3	101	26	92	63	22	72	27	70	65	61		0.63	− 3.7	4	5,259	s.	30	ne.	11	22	7	2	2.7		
Valentine	2,598	47	54	27.27	29.92	− .01	76.3	+ 3.1	107	26	90	50	21	63	38	65	59	62		1.34	− 2.1	6	8,136	s.	39	se.	5	15	13	3	3.5		
Sioux City	1,135	94	164	28.76	29.93	− .02	78.1	+ 3.9	101	26	88	59	6	68	29	68	64	66		4.16	+ 0.6	9	8,076	s.	38	w.	13	16	12	3	3.8		
Huron	1,306	59	74	28.57	29.94	.00	74.2	+ 2.7	97	26	85	57	21	63	29	66	63	71		4.83	+ 1.9	10	7,385	se.	35	s.	2	19	8	4	3.2		
Pierre	1,572	70	75	28.28	29.90	− .03	76.8	+ 1.6	102	29	89	55	19	65	38	65	60	61		2.80	+ 0.4	7	6,253	e.	36	ne.	20	14	10	7	443		
Yankton	1,233	49	57	28.62	29.91	− .03	77.6	+ 3.0	99	9	88	56	6	67	32					2.65	− 0.9	9	5,591	s.	30	nw.	20	14	14	4	4.3		

TABLE I.—*Climatological data for Weather Bureau Stations, July, 1919*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.						Total.	Departure from normal.	Days with .01 or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F	°F		°F	°F		°F	°F		°F	°F	%	*In.*	*In.*		*Miles*							*0–10*	*In.*	*In.*
Northern Slope.							**71.9**	**+ 3.8**											**47**	**1.63**	**0.0**								**3.7**		
Billings	3,140	5	....	....	....	....	72.4	....	102	25	90	40	19	55	52	....	....	....	....	0.75	....	4	....	ne.	....	....	....	22	7	2	....	....	....
Havre	2,505	11	44	27.32	29.90	− .01	71.8	+ 3.7	103	16	87	45	27	57	41	56	45	47	0.12	− 1.8	3	5,147	nw.	33	nw.	17	25	5	1	2.4	....	....
Helena	4,110	87	114	25.81	29.89	− .03	72.0	+ 5.4	99	16	87	46	7	57	39	53	39	35	0.16	− 0.9	4	6,441	sw	36	sw.	11	19	11	1	2.7	....	....
Kalispell	2,962	11	34	26.90	29.89	− .03	67.0	+ 2.7	99	16	83	40	18	51	46	50	35	38	0.88	0.0	4	4,784	nw.	40	sw.	31	23	5	3	2.8	....	....
Miles City	2,371	26	48	27.43	29.91	− .01	77.5	+ 4.6	104	25	91	52	19	64	38	61	52	49	1.12	− 0.2	6	4,956	ne.	36	w.	12	20	9	2	2.5	....	....
Rapid City	3,259	50	58	26.61	29.93	.00	74.4	+ 4.2	102	22	87	56	3	62	42	60	51	49	2.33	− 0.2	9	6,307	n.	40	n.	3	14	14	3	4.1	....	....
Cheyenne	6,088	84	101	24.10	29.90	− .02	69.8	+ 2.4	94	9	82	50	19	57	38	57	49	55	2.83	+ 0.8	8	7,240	w.	39	w.	24	12	13	6	4.7	....	....
Lander	5,372	60	68	24.69	29.88	− .04	73.0	+ 5.0	96	10	89	46	19	57	43	54	39	35	1.42	+ 0.6	5	4,008	sw.	42	w.	17	16	11	4	3.7	....	....
Sheridan	3,790	10	47	26.10	29.91	.....	72.6	.....	101	17	89	42	8	56	50	58	48	49	0.37	.....	6	4,311	nw.	39	w.	12	19	8	4	3.2	....	....
Yellowstone Park	6,200	11	48	23.97	29.93	+ .01	64.8	+ 3.3	91	10	81	36	19	49	45	48	36	45	0.80	− 0.4	8	5,374	sw.	38	sw.	17	18	12	1	2.8	....	....
North Platte	2,821	11	51	27.08	29.94	+ .01	77.2	+ 3.3	103	26	90	52	21	64	40	65	61	66	4.98	+ 2.3	5	4,614	s.	28	nw.	5	25	2	4	2.4	....	....
Middle Slope.							**79.2**	**+ 2.8**											**59**	**1.88**	**− 1.1**								**3.3**		
Denver	5,292	106	113	24.79	29.91	.00	74.9	+ 3.1	95	10	87	56	16	63	31	60	52	54	5.24	+ 3.6	8	5,262	s.	38	e.	27	9	17	5	4.9	....	....
Pueblo	4,685	80	86	25.33	29.90	− .01	76.0	+ 4.2	99	26	90	54	24	62	41	60	53	56	2.95	+ 1.0	9	4,652	nw.	33	nw.	26	18	9	4	3.8	....	....
Concordia	1,392	50	58	28.50	29.93	− .02	81.6	+ 3.5	103	11	93	57	22	70	32	68	62	57	0.03	− 3.6	1	5,806	s.	27	nw.	5	20	9	2	3.2	....	....
Dodge City	2,509	11	51	27.41	29.94	+ .01	79.6	+ 1.9	100	11	91	56	22	68	32	67	60	61	1.83	− 1.6	5	7,858	s.	32	se.	4	19	7	5	3.0	....	....
Wichita	1,358	139	158	28.56	29.95	− .01	81.4	+ 2.4	100	10	92	65	23	71	28	69	64	61	0.71	− 2.9	5	8,939	s.	33	sw.	25	25	5	1	2.0	....	....
Altus	1,410	5	....	....	....	....	80.7	.....	102	11	72	61	17	69	33	....	....	....	3.94	.....	7	....	....	....	....	....	19	5	7	....	....	....
Muskogee	652	4	....	....	....	....	83.5	.....	102	11	96	64	17	71	31	....	....	....	0.63	.....	3	....	se.	....	....	....	22	9	0	....	....	....
Oklahoma	1,214	10	47	28.73	29.97	+ .01	81.4	+ 1.6	98	10	92	65	17	71	27	71	66	65	0.53	− 3.1	3	7,987	s.	37	ne.	5	22	5	4	2.7	....	....
Southern Slope.							**78.4**	**− 2.1**											**66**	**1.72**	**− 1.1**								**3.8**		
Abilene	1,738	10	52	28.19	29.95	+ .02	79.9	− 2.3	97	18	90	66	25	70	27	70	66	68	1.51	− 0.9	5	6,749	s.	30	nw.	19	19	8	4	3.2	....	....
Amarillo	3,676	10	49	26.32	29.97	+ .05	76.2	+ 0.1	95	11	88	61	22	65	29	65	61	67	1.75	− 1.4	7	8,341	s.	35	se.	15	17	11	3	3.8	....	....
Del Rio	944	64	71	28.97	29.93	+ .03	81.1	− 3.6	99	19	89	69	24	73	23	....	....	....	3.48	+ 1.2	13	7,596	se.	32	n.	20	8	15	8	5.0	....	....
Roswell	3,566	75	85	26.38	29.90	+ .02	76.2	− 2.7	95	12	88	59	23	64	30	65	59	62	0.15	− 3.3	5	5,174	s.	37	e.	15	15	15	1	3.4	....	....
Southern Plateau.							**81.2**	**− 0.2**											**50**	**1.40**	**+ 0.2**								**3.4**		
El Paso	3,762	110	133	26.18	29.84	.00	79.4	− 1.1	95	8	90	64	12	69	30	64	57	54	1.87	− 0.3	12	7,838	se	46	s.	13	16	13	2	3.8	....	....
Santa Fe	7,013	57	66	23.36	29.88	.00	67.8	+ 0.9	85	12	78	54	22	58	26	56	52	67	4.02	+ 1.3	16	3,872	e.	24	nw.	29	4	24	3	5.5	....	....
Flagstaff	6,908	8	57	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Phoenix	1,108	11	81	28.68	29.79	+ .01	88.2	− 2.2	110	25	100	72	15	76	33	72	65	54	1.05	0.0	10	3,861	e.	42	se.	26	16	11	4	3.3	....	....
Yuma	141	9	54	29.62	29.76	.00	91.2	+ 0.3	113	9	104	73	20	78	35	73	65	49	0.06	− 0.1	2	4,916	s.	42	se.	27	22	5	4	2.3	....	....
Independence	3,910	11	42	25.94	29.87	+ .04	79.6	+ 1.1	99	10	95	54	29	64	36	57	39	28	T.	− 0.1	0	4,414	se.	29	se.	1	24	7	0	2.0	....	....
Needles	488	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Middle Plateau.							**76.2**	**+ 3.4**											**35**	**0.37**	**− 0.2**								**22**		
Reno	4,532	74	81	25.46	29.86	− .01	73.2	+ 5.7	99	20	91	45	31	55	42	53	39	37	T.	− 0.1	0	5,455	w.	41	se.	14	29	2	0	0.9	....	....
Tonopah	6,090	12	20	24.10	29.86	.....	75.6	.....	91	8	87	57	2	64	27	52	34	26	0.34	0.0	4	6,274	se.	32	e.	15	27	4	0	1.5	....	....
Winnemucca	4,344	18	56	25.60	29.89	− .01	74.0	+ 2.4	100	9	92	43	1	55	48	52	33	27	T.	− 0.2	0	4,457	sw.	29	sw.	9	27	4	0	0.9	....	....
Modena	5,749	10	43	24.65	29.86	.00	73.4	+ 3.7	97	9	89	51	3	58	42	55	43	44	1.37	+ 0.1	10	8,442	sw.	38	e.	15	14	15	2	3.8	....	....
Salt Lake City	4,360	163	203	25.59	29.84	− .06	80.2	+ 4.0	98	10	92	59	8	68	32	59	46	34	0.06	− 0.5	3	5,661	nw.	34	s.	27	21	7	3	2.2	....	....
Grand Junction	4,602	82	96	25.38	29.88	− .01	80.2	+ 1.0	100	27	94	60	17	66	35	60	48	40	0.46	0.0	7	4,402	se.	33	se.	8	14	13	4	3.9	....	....
Northern Plateau.							**73.9**	**+ 3.0**											**31**	**0.07**	**− 0.4**								**2.2**		
Baker	3,471	48	53	26.44	29.95	.00	68.4	+ 3.4	99	9	86	39	7	51	48	51	36	36	T.	− 0.4	0	4,427	nw.	18	n.	5	22	7	2	2.3	....	....
Boise	2,739	78	86	27.10	29.88	− .03	75.6	+ 2.8	104	9	92	48	18	59	44	55	37	29	T.	− 0.2	0	3,787	nw.	23	nw.	22	27	4	0	1.1	....	....
Lewiston	757	40	48	29.13	29.92	− .03	76.4	+ 2.8	108	15	94	51	18	59	49	....	....	....	T.	− 0.4	0	3,022	e.	25	nw.	5	20	9	2	2.1	....	....
Pocatello	4,477	60	68	25.46	29.85	− .07	75.0	+ 3.8	99	10	91	48	19	59	45	52	32	27	0.27	− 0.4	2	6,462	se.	48	s.	24	20	9	2	2.6	....	....
Spokane	1,929	101	110	27.92	29.92	− .04	71.8	+ 3.0	102	15	87	47	7	56	44	53	37	34	0.07	− 0.6	2	4,407	sw.	27	sw.	5	16	14	1	3.2	....	....
Walla Walla	991	57	65	28.87	29.92	− .05	76.4	+ 2.3	104	15	91	52	7	62	46	57	40	31	0.09	− 0.3	2	3,582	s.	20	sw.	5	22	8	1	2.1	....	....
North Pacific Coast Region.							**61.5**	**+ 5.0**											**61**	**0.16**	**− 5.4**								**4.0**		
North Head	211	11	56	29.87	30.10	+ .02	53.0	− 4.7	63	12	56	46	20	50	12	52	51	92	0.10	− 0.4	4	12,873	nw.	40	n.	9	4	10	17	7.2	....	....
North Yakima	1,071	4	....	....	....	.....	73.5	.....	104	15	90	42	6	57	46	....	....	....	0.03	.....	1	....	nw.	....	....	....	20	7	4	....	....	....
Port Angeles	29	8	48	30.08	30.11	.....	55.6	.....	82	14	65	42	1	46	35	....	....	....	0.17	− 0.2	3	5,265	nw.	32	w.	16	22	1	8	2.6	....	....
Seattle	125	215	259	29.95	30.08	+ .04	63.0	− 0.5	85	15	72	49	18	53	28	55	48	64	0.22	− 0.5	3	5,327	n.	32	sw.	5	19	4	8	3.4	....	....
Tacoma	213	113	120	29.84	30.06	.00	63.0	− 0.4	85	15	73	48	1	53	27	55	50	65	0.05	− 0.6	1	4,389	n.	24	sw.	5	13	10	8	4.9	....	....
Tatoosh Island	86	7	57	29.99	30.09	+ .04	52.6	− 2.5	62	7	56	46	27	49	13	51	50	94	0.31	− 1.5	10	7,646	sw.	29	s.	28	14	4	13	5.1	....	....
Medford	1,425	4	....	....	....	.....	72.8	.....	105	14	92	41	26	53	52	....	....	....	0.03	.....	1	....	nw.	....	....	....	24	5	2	....	....	....
Portland, Oreg	153	68	106	29.86	30.02	− .03	68.0	+ 1.7	100	14	80	49	7	56	35	57	50	570.23	− 0.3	4	4,892	nw.	19	nw.	24	22	3	6	2.6	....	....
Roseburg	510	9	57	29.47	30.01	− .02	69.3	+ 3.2	103	14	85	42	26	53	47	56	47	54	0.06	− 0.3	2	3,122	n.	20	n.	17	20	10	1	2.0	....	....
Middle Pacific Coast Region.							**64.7**	**− 4.7**											**59**	**0.0**	**0.0**								**2.9**		
Eureka	62	73	89	29.97	30.04	− .01	54.2	+ 1.1	64	8	58	46	26	50	14	51	49	87	0.01	− 0.1	1	4,938	nw.	28	n.	6	5	12	14	6.4	....	....
Mount Tamalpais	2,375	11	18	27.50	29.93	− .02	68.0	− 2.5	90	8	76	43	28	60	26	53	39	40	T.	0.0	0	9,746	nw.	58	nw.	11	28	3	0	0.6	....	....
Point Reeves Light	490	7	18	29.40	29.92	.....	52.8	− 0.9	71	7	57	45	2	48	24	....	....	....	T.	.....	0	15,166	nw.	55	nw.	12	7	5	19	7.0	....	....
Red Bluff	332	50	56	29.48	29.83	− .06	82.6	+ 0.5	108	18	98	54	29	67	40	62	46	32	0	0.0	0	3,558	se.	20	nw.	7	31	0	0	0.1	....	....
Sacramento	69	106	117	29.79	29.86	− .02	72.8	+ 0.3	106	8	90	50	5	56	45	60	52	56	T.	0.0	0	6,767	s.	23	s.	28	30	1	0	0.3	....	....
San Francisco	155	208	243	29.78	29.95	.00	57.0	− 0.3	78	7	63	47	3	51	25	52	50	82	0.01	0.0	1	10,472	sw.	36	w.	1	14	12	5	4.3	....	....
San Jose	141	12	110	29.81	29.96	.....	65.4	− 1.5	95	7	79	44	1	52	49	....	....	....	T.	0.0	0	4,538	nw.	23	se.	27	28	3	0	1.6	....	....
South Pacific Coast Region.							**71.4**	**+ 0.8**											**65**	**0.0**	**0.0**								**1.8**		
Fresno	327	89	98	29.49	29.83	.00	82.9	+ 0.9	106	11	100	56	28	66	39	60	43	31	0	0.0	0	6,576	nw.	25	nw.	9	31	0	0	0.0	....	....
Los Angeles	338	159	191	29.55	29.90	.00	71.0	+ 0.6	87	23	80	55	1	61	25	62	58	73	0	0.0	0	4,088	sw.	16	sw.	19	26	5	0	1.5	....	....
San Diego	87	62	70	29.82	29.91	− .01	68.6	+ 1.7	79	23	74	60	2	64	15	64	61	81	T.	0.0	0	4,138	w.	17	nw.	29	20	10	1	3.4	....	....
San Luis Obispo	201	32	40	29.74	29.95	.00	63.2	.00	90	9	75	43	2	51	39	54	49	73	T.	0.0	0	2,597	nw.	12	w.	23	28	3	0	2.2	....	....
West Indies.																																	
San Juan, P. R	82	8	54	29.94	30.03	+ .04	79.0	.....	86	4	84	70	29	74	15	....	....	....	8.03	+ 1.6	21	9,182	e.	40	e.	9	4	19	8	5.7	....	....
Panama Canal.																																	
Balboa Heights	118	7	97	29.71	29.83	− .02	80.6	+ 0.3	91	14	87	77	8	74	17	76	75	89	4.75	− 2.9	15	5,150	nw.	25	s.	28	0	16	15	7.4	....	....
Colon	36	30	97	29.80	29.84	− .09	80.2	+ 0.3	87	6	84	73	8	76	12	77	76	89	13.60	− 2.4	28	6,620	w.	32	n.	14	0	4	27	8.8	....	....

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during July, 1919, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	19			0.70														0.47			
Albany, N. Y.	21			1.04														0.34			
Alpena, Mich.	4			0.50														0.40			
Amarillo, Tex.	17	3:35 p. m.	5:05 p. m.	1.27	3:39 p. m.	4:07 p. m.	0.01	0.27	0.54	0.76	0.92	1.07	1.19								
Anniston, Ala.	8			0.54														0.53			
Asheville, N. C.	20	2:15 p. m.	3:55 p. m.	0.75	2:24 p. m.	2:48 p. m.	0.02	0.22	0.32	0.36	0.47	0.53									
Atlanta, Ga.	5	2:37 p. m.	4:00 p. m.	0.70	3:27 p. m.	3:37 p. m.	0.17	0.40	0.52												
	8–9	6:30 p. m.	D.N.a.m.	1.27	6:47 p. m.	7:17 p. m.	0.01	0.12	0.26	0.40	0.54	0.66	0.74								
	9–10	10:48 p. m.	D.N.a.m.	1.19	10:53 p. m.	11:41 p. m.	0.01	0.22	0.28	0.34	0.41	0.52	0.62	0.70	0.78	0.87	0.92				
	18	1:55 p. m.	2:30 p. m.	0.98	2:03 p. m.	2:23 p. m.	0.02	0.29	0.61	0.83	0.96										
Atlantic City, N. J.	13	7:05 a. m.	10:30 a. m.	1.39	7:13 a. m.	7:43 a. m.	0.01	0.07	0.32	0.58	0.84	0.98	1.07								
Augusta, Ga.	16	1:50 p. m.	4:10 p. m.	1.55	2:31 p. m.	3:21 p. m.	0.18	0.27	0.46	0.54	0.65	0.75	0.86	0.94	0.96	1.14	1.31				
	18–19	4:20 p. m.	D.N.a.m.	1.29	4:31 p. m.	4:47 p. m.	0.01	0.14	0.40	0.53	0.57										
	20	1:10 p. m.	4:05 p. m.	0.65	1:21 p. m.	1:48 p. m.	0.03	0.11	0.22	0.35	0.46	0.54	0.58								
	24–25	4:20 p. m.	D.N.a.m.	1.44	5:49 p. m.	6:00 p. m.	0.01	0.45	0.55	0.59											
Baker, Oreg.	29			T.														T.			
Baltimore, Md.	15	6:00 a. m.	9:25 a. m.	0.59	7:52 a. m.	8:11 a. m.	0.01	0.10	0.30	0.44	0.50										
Bentonville, Ark.	29	12:05 p. m.	1:05 p. m.	1.45	12:12 p. m.	12:50 p. m.	0.05	0.26	0.32	0.42	0.53	1.09	1.25	1.35							
Binghamton, N. Y.	15			0.58														0.39			
Birmingham, Ala.	8	11:01 a. m.	11:58 a. m.	0.67	11:10 a. m.	11:38 a. m.	0.01	0.17	0.34	0.44	0.51	0.60	0.65								
Bismarck, N. Dak.	29–30			0.56														0.09			
Block Island, R. I.	19			1.68														0.49			
Boise, Idaho.	11			T.														T.			
Boston, Mass.	22	1:05 p. m.	2:10 p. m.	0.54	1:34 p. m.	1:50 p. m.	T.	0.22	0.33	0.48	0.53										
Buffalo, N. Y.	26			0.30														0.28			
Burlington, Vt.	21			0.30														0.23			
Cairo, Ill.	6			0.73														0.43			
Canton, N. Y.	15			0.87														0.76			
Charles City, Iowa.	13	8:04 p. m.	10:00 p. m.	1.65	8:41 p. m.	9:21 p. m.	0.03	0.15	0.38	0.65	1.01	1.19	1.25	1.32	1.41						
	13–14	11:15 p. m.	12:15 a. m.	1.15	11:34 p. m.	12:07 a. m.	0.04	0.24	0.55	0.71	0.83	0.94	1.07	1.11							
					1:58 a. m.	3:14 a. m.	0.29	0.13	0.23	0.32	0.50	0.77	0.83	0.94	1.02	1.04	1.11	1.46	1.94		
Charleston, S. C.	21–22	7:40 p. m.	2:05 p. m.	5.52	3:49 a. m.	4:09 a. m.	2.29	0.17	0.43	0.55	0.66										
					7:47 a. m.	8:48 a. m.	3.48	0.20	0.30	0.36	0.36	0.37	0.43	0.51	0.58	0.67	0.75	1.07	1.13		
Charlotte, N. C.	23	D.N.a.m.	8:36 a. m.	1.86	4:28 a. m.	5:13 a. m.	0.02	0.17	0.43	0.70	0.91	1.03	1.18	1.32	1.45	1.52					
Chattanooga, Tenn.	12			0.52														0.50			
Cheyenne, Wyo.	14			0.62														0.48			
Chicago, Ill.	31			1.02														0.39			
Cincinnati, Ohio.	15			0.83														0.52			
Cleveland, Ohio.	5			0.55														0.47			
Columbia, Mo.	8	2:35 p. m.	4:07 p. m.	0.96	2:53 p. m.	3:10 p. m.	0.05	0.28	0.72	0.83	0.88										
Columbia, S. C.	7–8	9:00 p. m.	D.N.a.m.	1.38	9:40 p. m.	10:17 p. m.	0.12	0.06	0.24	0.37	0.65	0.86	0.96	1.05	1.09						
	19	1:45 p. m.	4:15 p. m.	0.81	2:09 p. m.	2:28 p. m.	0.07	0.11	0.28	0.44	0.56										
Columbus, Ohio.	12–13	10:20 p. m.	6:18 a. m.	1.52	10:46 p. m.	11:06 p. m.	0.01	0.22	0.54	0.89	1.01										
	31	1:30 p. m.	4:10 p. m.	0.60	1:32 p. m.	1:45 p. m.	T.	0.23	0.43	0.50											
Concord, N. H.	16			0.41														0.15			
Concordia, Kans.	4			0.03														0.02			
Corpus Christi, Tex.	23	5:31 a. m.	10:25 a. m.	1.47	9:50 a. m.	10:15 a. m.	0.61	0.10	0.36	0.61	0.75	0.82									
	24	D. N. a.m.	10:45 a. m.	1.59	8:35 a. m.	8:54 a. m.	0.12	0.20	0.49	0.53	0.59										
					9:45 a. m.	10:04 a. m.	0.81	0.11	0.44	0.57	0.70										
Dallas, Tex.	17	10:57 a. m.	1:26 p. m.	0.80	11:21 a. m.	11:53 a. m.	0.01	0.07	0.28	0.39	0.44	0.50	0.59	0.61							
Davenport, Iowa.	9	3:45 p. m.	7:13 p. m.	1.88	4:13 p. m.	5:27 p. m.	0.01	0.22	0.51	0.95	1.18	1.24	1.39	1.43	1.45	1.46	1.47	1.62	1.84		
Dayton, Ohio.	20			2.36														0.66			
Del Rio, Tex.	27			0.95														0.49			
Denver, Colo.	2	4:30 p. m.	11:00 p. m.	1.34	4:40 p. m.	5:37 p. m.	0.04	0.10	0.20	0.34	0.44	0.49	0.52	0.63	0.65	0.76	0.87	0.99			
	31–1	6:15 p. m.	D. N.a.m.	2.59	6:55 p. m.	7:55 p. m.	0.04	0.20	0.43	0.76	1.02	1.25	1.39	1.56	1.62	1.67	1.78	1.90			
Des Moines, Iowa.	31	4:14 p. m.	6:38 p. m.	1.21	4:23 p. m.	4:39 p. m.	0.01	0.39	0.85	1.01	1.03										
Detroit, Mich.	14	3:51 p. m.	4:23 p. m.	0.93	3:53 p. m.	4:14 p. m.	0.01	0.13	0.35	0.64	0.88	0.92									
Devils Lake, N. Dak.	1	6:23 a. m.	6:50 a. m.	0.58	6:28 a. m.	6:43 a. m.	0.01	0.15	0.36	0.55											
Dodge City, Kans.	19	6:45 p. m.	7:45 p. m.	0.64	7:01 p. m.	7:36 p. m.	0.03	0.07	0.12	0.23	0.35	0.43	0.52	0.59							
Drexel, Nebr.	4			0.39														0.17			
Dubuque, Iowa.	4	2:55 p. m.	6:40 p. m.	1.47	3:11 p. m.	3:26 p. m.	0.02	0.09	0.48	0.68											
	9	11:15 a. m.	3:40 p. m.	3.82	1:51 p. m.	2:36 p. m.	1.13	0.17	0.51	1.17	1.71	1.91	2.16	2.40	2.51	2.64					
	30	7:40 p. m.	D. N. p. m.	0.90	8:17 p. m.	8:54 p. m.	0.03	0.05	0.08	0.13	0.19	0.30	0.42	0.61	0.66						
Duluth, Minn.	8			0.88														0.68			
Eastport, Me.	23			0.35														0.26			
Elkins, W. Va.	10	6:35 p. m.	8:10 p. m.	0.73	6:49 p. m.	7:19 p. m.	0.02	0.16	0.24	0.30	0.45	0.52	0.60								
		8:50 p. m.	D. N.p. m.	1.40	8:58 p. m.	9:47 p. m.	0.03	0.18	0.33	0.64	0.75	0.85	0.95	1.02	1.10	1.20	1.30				
	13	D. N.a.m.	5:20 a. m.	1.24	2:24 a. m.	2:57 a. m.	0.02	0.12	0.30	0.35	0.43	0.49	0.64	0.71							
	15–16	11:55 p. m.	8:12 a. m.	1.68	2:56 a. m.	3:28 a. m.	0.61	0.11	0.19	0.25	0.33	0.46	0.51	0.55							
Ellendale, N. Dak.	2	6:46 p. m.	D. N.p. m.	1.15	6:57 p. m.	7:21 p. m.	0.01	0.15	0.32	0.41	0.50	0.57									
El Paso, Tex.	13	3:20 p. m.	4:45 p. m.	0.84	3:33 p. m.	4:01 p. m.	0.02	0.22	0.31	0.45	0.63	0.69	0.76								
Erie, Pa.	10			1.04														0.60			
Escanaba, Mich.	26			0.66														0.26			
Eureka, Calif.	28			T.														T.			
Evansville, Ind.	5	6:45 p. m.	7:18 p. m.	0.77	6:48 p. m.	7:12 p. m.	0.01	0.14	0.33	0.45	0.58	0.76									
Fort Smith, Ark.	1			0.12														0.08			
Fort Wayne, Ind.	31	2:00 a. m.	3:45 a. m.	1.40	2:05 a. m.	2:55 a. m.	0.01	0.09	0.13	0.24	0.27	0.28	0.30	0.43	0.75	1.04	1.13				
Fort Worth, Tex.	18	3:13 a. m.	12:16 p. m.	2.90	6:05 a. m.	6:36 a. m.	0.86	0.05	0.15	0.24	0.33	0.65	0.86	0.94							
	20	5:24 p. m.	6:09 p. m.	0.70	5:35 p. m.	6:00 p. m.	0.01	0.17	0.36	0.51	0.59	0.65									
Fresno, Calif.	‡			‡														‡			
Galveston, Tex.	22	6:47 a. m.	5:50 p. m.	1.28	8:42 a. m.	9:00 a. m.	0.12	0.11	0.35	0.62	0.69										
Grand Haven, Mich.	27			0.39														0.36			
Grand Junction, Colo.	6			0.19														0.19			
Grand Rapids, Mich.	30			0.29														0.14			
Green Bay, Wis.	14	3:30 a. m.	5:25 a. m.	2.52	4:01 a. m.	4:50 a. m.	0.17	0.18	0.50	0.67	0.99	1.38	1.63	1.72	1.84	2.10	2.16				
Greenville, S. C.	16	12:55 p. m.	2:00 p. m.	0.86	1:02 p. m.	1:30 p. m.	0.01	0.11	0.22	0.27	0.35	0.69	0.84								
Hannibal, Mo.	9–10	D.N.p. m.	D.N.a. m.	1.15	10:14 p. m.	10:38 p. m.	0.02	0.22	0.58	0.75	0.92	1.00									
	14	2:51 p. m.	4:55 p. m.	0.92	3:02 p. m.	3:28 p. m.	0.01	0.15	0.37	0.60	0.69	0.81	0.84								
Harrisburg, Pa.	15	4:22 p. m.	5:30 p. m.	0.87	4:22 p. m.	4:38 p. m.	0.00	0.22	0.62	0.80	0.84										
	22	3:10 p. m.	D.N.p. m.	0.89	3:58 p. m.	4:16 p. m.	0.12	0.09	0.25	0.39	0.50										
Hartford, Conn.	6			0.58														0.34			
Hatteras, N. C.	29			0.69														0.68			
Havre, Mont.	2			0.06														0.03			
Helena, Mont.	11			0.12														0.12			
Houghton, Mich.	21			1.43														0.61			
Houston, Tex.	12	3:13 p. m.	4:10 p. m.	0.92	3:36 p. m.	3:57 p. m.	0.09	0.19	0.38	0.60	0.74	0.82									
	22	4:50 a. m.	4:05 p. m.	1.77	5:49 a. m.	6:20 a. m.	0.09	0.19	0.38	0.63	0.81	0.93	0.99	1.00							
	23	11:44 a. m.	3:48 p. m.	2.02	12:05 p. m.	12:55 p. m.	0.03	0.22	0.42	0.55	0.69	0.79	0.93	1.10	1.30	1.42	1.48				
Huron, S. Dak.	18	5:20 p. m.	D.N.p. m.	2.72	6:47 p. m.	7:12 p. m.	0.13	0.24	0.43	0.49	0.63	0.69									
					7:45 p. m.	9:38 p. m.	1.07	0.05	0.10	0.17	0.23	0.29	0.36	0.47	0.54	0.60	0.65	0.81	0.96	1.18	1.64
	28	D.N.a.m.	D.N.a.m.	0.64	2:57 a. m.	3:21 a. m.	0.02	0.08	0.24	0.38	0.53	0.58									

*Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during July, 1919, at all stations furnished with self-registering gages—Continued.*

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated. 5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Independence, Calif.	16			T.														T.			
Indianapolis, Ind.	9			0.58														0.49			
Iola, Kans.	4–5	7:15 p. m.	D.N.a. m.	0.90	7:38 p. m.	8:18 p. m.	0.02	0.06	0.16	0.34	0.48	0.56	0.61	0.71	0.78						
Jacksonville, Fla.	a 30–1	6:30 p. m.	6:30 a. m.	1.89	2:08 a. m.	2:30 a. m.	0.39	0.15	0.33	0.44	0.49	0.54									
					3:35 a. m.	4:13 a. m.	1.02	0.14	0.34	0.37	0.56	0.62	0.67	0.78	0.83						
Kalispell, Mont.	31			0.33														0.27			
Kansas City, Mo.	29			0.26														0.25			
Keokuk, Iowa.	31–1	10:45 p. m.	1:05 a. m.	1.06	10:47 p. m.	11:17 p. m.	0.01	0.14	0.40	0.59	0.69	0.82	0.92								
Key West, Fla.	6	10:45 a. m.	12: noon.	0.68	11:05 a. m.	11:24 a. m.	0.08	0.14	0.30	0.44	0.54										
	25	5:38 p. m.	6:45 p. m.	0.70	5:49 p. m.	6:02 p. m.	0.07	0.20	0.38	0.54											
		8:36 a. m.	12:15 p. m.	1.33	10:18 a. m.	10:45 a. m.	0.53	0.13	0.32	0.41	0.62	0.69	0.72								
Knoxville, Tenn.	31	8:30 p. m.	D.N.p. m.	0.79	8:43 p. m.	9:05 p. m.	0.02	0.11	0.23	0.37	0.53	0.58									
La Crosse, Wis.	30	5:32 p. m.	7:30 p. m.	0.60	5:52 p. m.	6:03 p. m.	0.01	0.42	0.53	0.58											
Lander, Wyo.	14			0.48														0.48			
Lansing, Mich.	12			0.51														0.44			
Lewiston, Idaho.	10			T.														T.			
Lexington, Ky.	5	1:37 p. m.	2:50 p. m.	0.70	1:41 p. m.	2:06 p. m.	0.01	0.21	0.24	0.25	0.40	0.57									
Lincoln, Nebr.	31			0.30														0.21			
Little Rock, Ark.	8	1:27 p. m.	3:00 p. m.	1.20	1:40 p. m.	2:09 p. m.	0.01	0.19	0.30	0.49	0.94	1.08	1.15								
	30	10:51 a. m.	12:25 p. m.	0.61	11:26 a. m.	11:49 a. m.	0.03	0.09	0.29	0.34	0.44	0.50									
Los Angeles, Calif.	‡			‡														‡			
Louisville, Ky.	10	D.N.a. m.	D.N.a. m.	1.34	1:51 a. m.	2:17 a. m.	0.24	0.16	0.44	0.50	0.64	0.82	0.85								
	15	9:51 a. m.	10:30 a. m.	1.54	9:51 a. m.	10:15 a. m.	0.00	0.22	1.01	1.33	1.45	1.52									
Ludington, Mich.	14			0.85														0.44			
Lynchburg, Va.	15	3:15 p. m.	6:35 p. m.	0.90	3:26 p. m.	3:58 p. m.	0.01	0.20	0.41	0.51	0.56	0.62	0.68	0.76							
	17	4:18 p. m.	8:05 p. m.	1.20	4:21 p. m.	4:35 p. m.	0.01	0.28	0.50	0.58											
Macon, Ga.	18	7:10 a. m.	10:03 a. m.	1.06	7:43 a. m.	8:24 a. m.	0.12	0.07	0.19	0.35	0.46	0.52	0.61	0.68	0.74	0.76					
		4:05 p. m.	6:03 p. m.	1.53	4:07 p. m.	4:53 p. m.	0.01	0.12	0.19	0.28	0.42	0.65	0.80	1.03	1.13	1.20	1.21				
	22–23	11:45 p. m.	11:20 a. m.	1.93	2:08 a. m.	2:51 a. m.	0.01	0.18	0.30	0.39	0.52	0.55	0.59	0.62	0.74	0.79					
	24	2:46 p. m.	7:25 p. m.	1.00	2:47 p. m.	3:11 p. m.	0.01	0.27	0.38	0.47	0.61	0.68									
Madison, Wis.	14			0.56														0.54			
Marquette, Mich.	3			1.38														0.69			
Memphis, Tenn.	31			0.49														0.48			
Meridian, Miss.	16	D. N. a. m.	D. N. a. m.	0.78	3:02 a. m.	3:35 a. m.	0.10	0.08	0.18	0.22	0.34	0.39	0.58	0.67							
Miami, Fla.	1–2	D.N. p. m.	D. N. a. m.	0.72	10:39 p. m.	10:58 p. m.	0.01	0.26	0.44	0.53	0.59										
Milwaukee, Wis.	21	3:45 p. m.	4:20 p. m.	0.70	4:00 p. m.	4:15 p. m.	0.07	0.33	0.56	0.63											
Minneapolis, Minn.	13–14	D.N. p. m.	D. N. a. m.	2.22	11:21 p. m.	11:58 p. m.	0.43	0.26	0.50	0.51	0.51	0.52	0.98	1.49	1.60						
Mobile, Ala.	9	11:40 a. m.	12:25 p. m.	0.68	11:48 a. m.	12:10 p. m.	0.03	0.16	0.24	0.31	0.57	0.65									
	19	7:50 a. m.	9:35 a. m.	0.89	7:55 a. m.	8:18 a. m.	0.01	0.13	0.31	0.43	0.52	0.57									
Modena, Utah.	18			0.24														0.22			
Montgomery, Ala.	18	4:10 p. m.	5:00 p. m.	0.68	4:20 p. m.	4:44 p. m.	0.02	0.14	0.26	0.37	0.57	0.64									
	27	2:49 p. m.	8:00 p. m.	1.01	2:49 p. m.	3:11 p. m.	0.00	0.24	0.59	0.75	0.85	0.88									
Moorhead, Minn.	13	6:00 p. m.	7:15 p. m.	1.52	6:05 p. m.	6:44 p. m.	0.02	0.10	0.18	0.22	0.37	0.60	0.99	1.35	1.46						
	19	12:15 a. m.	5:10 a. m.	1.82	1:19 a. m.	2:38 a. m.	0.18	0.10	0.17	0.29	0.47	0.54	0.55	0.57	0.63	0.64	0.70	0.92	1.28		
Mount Tamalpais, Calif.	9			T.														T.			
Nantucket, Mass.	23			2.16														0.78			
Nashville, Tenn.	31			1.12														0.61			
New Haven, Conn.	19			0.49														0.37			
New Orleans, La.	12	5:47 p. m.	7:12 p. m.	1.53	5:53 p. m.	6:52 p. m.	0.01	0.16	0.37	0.61	0.79	0.86	0.96	1.05	1.15	1.25	1.35	1.45			
	19	10:00 a. m.	12:34 p. m.	0.85	10:16 a. m.	10:31 a. m.	0.02	0.15	0.48	0.65											
	25	5:37 p. m.	7:52 p. m.	1.83	5:42 p. m.	6:48 p. m.	0.01	0.11	0.27	0.36	0.38	0.41	0.49	0.67	0.94	1.19	1.35	1.54	1.72		
New York, N. Y.	19–20	12:35 p. m.	10:55 a. m.	3.27	12:52 p. m.	1:52 p. m.	0.02	0.07	0.13	0.26	0.42	0.52	0.60	0.66	0.73	0.74	0.81	0.99			
	31–1	2:30 p. m.	6:30 a. m.	1.12	8:25 p. m.	8:45 p. m.	1.32	0.08	0.32	0.51	0.64										
					2:20 a. m.	2:40 a. m.	0.23	0.07	0.24	0.43	0.57										
Norfolk, Va.	22			0.75														0.61			
Northfield, Vt.	28			0.20														0.17			
North Head, Wash.	5			0.06														0.02			
North Platte, Nebr.	3	1:47 p. m.	3:18 p. m.	1.21	2:04 p. m.	2:24 p. m.	0.04	0.33	0.66	0.88	0.96										
	5	2:23 a. m.	5:18 a. m.	1.35	3:26 a. m.	3:46 a. m.	0.01	0.22	0.56	1.02	1.21										
	13	4:41 p. m.	6:18 p. m.	0.73	5:00 p. m.	5:20 p. m.	0.11	0.18	0.38	0.49	0.56										
Oklahoma, Okla.	5			0.30														0.30			
Omaha, Nebr.	8			0.25														0.25			
Oswego, N. Y.	27			0.88														0.48			
Palestine, Tex.	26			0.47														0.46			
Parkersburg, W. Va.	15	4:37 p. m.	6:15 p. m.	0.83	4:37 p. m.	4:51 p. m.	0.00	0.21	0.56	0.80											
Pensacola, Fla.	17	10:04 a. m.	12:50 p. m.	1.33	10:11 a. m.	11:13 a. m.	0.01	0.05	0.12	0.23	0.34	0.39	0.44	0.50	0.53	0.62	0.73	1.09	1.25		
	19	1:35 a. m.	8:00 a. m.	2.52	3:50 a. m.	4:10 a. m.	0.60	0.44	0.61	0.72	0.81										
Peoria, Ill.	5	6:09 p. m.	8:00 p. m.	0.81	6:16 p. m.	7:05 p. m.	0.02	0.07	0.15	0.18	0.27	0.34	0.41	0.47	0.57	0.67	0.72				
	6	4:45 p. m.	6:10 p. m.	0.70	5:04 p. m.	5:44 p. m.	0.01	0.10	0.10	0.17	0.28	0.41	0.51	0.62	0.67						
Philadelphia, Pa.	12–13	11:23 p. m.	7:00 a. m.	1.79	12:07 a. m.	12:59 a. m.	0.03	0.06	0.11	0.25	0.53	0.57	0.59	0.79	1.15	1.38	1.56	1.63			
	20	12:15 p. m.	1:30 p. m.	0.75	12:26 p. m.	12:46 p. m.	0.01	0.15	0.16	0.32	0.74										
	21	9:20 a. m.	11:15 a. m.	0.99	10:26 a. m.	10:56 a. m.	0.13	0.13	0.15	0.15	0.32	0.60	0.83								
Phoenix, Ariz.	12			0.55														0.23			
Pierre, S. Dak.	4–5			1.12														0.62			
Pittsburgh, Pa.	10	2:45 p. m.	3:45 p. m.	0.90	2:52 p. m.	3:30 p. m.	0.04	0.07	0.19	0.43	0.44	0.48	0.55	0.77	0.83						
	14–15	9:15 p. m.	D. N. a. m.	2.13	10:04 p. m.	10:27 p. m.	0.05	0.11	0.34	0.48	0.81	0.86									
	15	12:15 p. m.	D.N. p. m.	1.63	12:22 p. m.	12:42 p. m.	0.01	0.14	0.52	0.85	0.98										
Pocatello, Idaho.	31			0.10														0.10			
Point Reyes Light, Calif.	9			T.														T.			
Port Angeles, Wash.	31			0.14														0.09			
Port Huron, Mich.	14			0.32														0.31			
Portland, Me.	6			0.57														0.38			
Portland, Oreg.	23			0.13														0.12			
Providence, R. I.	23			1.32														0.46			
Pueblo, Colo.	19	6:40 p. m.	7:25 p. m.	0.83	6:43 p. m.	7:04 p. m.	0.01	0.33	0.60	0.71	0.79										
	25	4:30 p. m.	6:05 p. m.	1.13	4:35 p. m.	5:16 p. m.	0.01	0.12	0.22	0.50	0.76	0.82	0.89	0.95	1.03						
Raleigh, N. C.	7	D.N. a. m	12:30 p. m.	1.76	6:08 a. m.	6:43 a. m.	0.17	0.12	0.19	0.28	0.35	0.43	0.47	0.61							
	16	4:52 p. m.	D.N.p.m.	1.87	6:15 p. m.	8:00 p. m.	0.52	0.10	0.19	0.22	0.28	0.32	0.41	0.52	0.59	0.65	0.75	1.00	1.16		
	22–23	7:05 p. m.	2:00 p. m.	2.87	9:48 p. m.	10:12 p. m.	0.33	0.06	0.12	0.47	0.60	0.64									
Rapid City, S. Dak.	16			0.46														0.45			
Reading, Pa.	15	2:50 a. m.	4:40 a. m.	0.54	4:08 a. m.	4:26 a. m.	0.03	0.19	0.39	0.47	0.50										
Red Bluff, Calif.	‡			‡														‡			
Reno, Nev.	9			T.														T.			
Richmond, Va.	17–8	3:20 p. m.	12:00 noon.	1.72	1:03 a. m.	1:57 a. m.	0.33	0.19	0.26	0.29	0.33	0.40	0.47	0.58	0.69	0.81	0.91	1.01			
Rochester, N. Y.	21	2:17 p. m.	3:00 p. m.	0.95	2:29 p. m.	2:44 p. m.	0.03	0.33	0.72	0.89											
Roseburg, Oreg.	22			0.05														0.04			
Roswell, N. Mex.	15			0.05														0.04			
Sacramento, Calif.	9			T.														T.			
Saginaw, Mich.	27	7:08 p. m.	10:50 p. m.	0.91	9:13 p. m.	9:28 p. m.	0.09	0.23	0.47	0.65											

a June 30. * Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during the month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during July, 1919, at all stations furnished with self-registering gages—Continued.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
St. Joseph, Mo.	31			1.58														0.79			
St. Louis, Mo.	11			0.79														*			
St. Paul, Minn.	13–14	11:05 p. m.	3:00 a. m.	2.72	11:07 p. m.	12:16 a. m.	0.01	0.14	0.25	0.52	0.79	1.19	1.52	1.62	1.70	1.71	1.88	2.20	2.48		
	20	3:50 p. m.	7:15 p. m.	1.64	4:20 p. m.	5:25 p. m.	0.04	0.11	0.26	0.51	0.75	0.82	0.83	0.83	0.87	1.04	1.26	1.42	1.50		
Salt Lake City, Utah	25			0.03														0.03			
San Antonio, Tex.	21	7:03 a. m.	10:25 a. m.	1.26	7:10 a. m.	7:41 a. m.	0.03	0.06	0.10	0.22	0.55	0.85	0.97	1.01							
	22	1:23 p. m.	4:00 p. m.	0.67	1:25 p. m.	1:58 p. m.	0.01	0.18	0.32	0.34	0.34	0.34	0.53	0.62							
San Diego, Calif.	8			T.														T.			
Sandusky, Ohio	6	5:25 a. m.	8:50 a. m.	0.94	8:01 a. m.	8:30 a. m.	0.39	0.10	0.21	0.24	0.26	0.34	0.52								
Sandy Hook, N. J.	16			1.20														0.70			
San Francisco, Calif.	5			0.01														0.01			
San Jose, Calif.	9			T.														T.			
San Luis Obispo, Calif.	8			T.														T.			
Santa Fe, N. Mex.	14			1.37														0.56			
Sault Ste. Marie, Mich.	4			0.34														0.23			
Savannah, Ga.	14	7:40 p. m.	9:40 p. m.	0.62	7:55 p. m.	8:15 p. m.	0.02	0.14	0.33	0.46	0.53										
	17	11:20 a. m.	2:56 p. m.	1.22	1:10 p. m.	1:29 p. m.	0.62	0.15	0.34	0.50	0.55										
	24	11:05 a. m.	12:42 p. m.	1.18	11:21 a. m.	11:47 a. m.	0.02	0.14	0.35	0.69	0.89	1.14	1.16								
Scranton, Pa.	19			1.54														0.95			
Seattle, Wash.	31			0.13														0.10			
Sheridan, Wyo.	12			0.30														0.30			
Shreveport, La.	19			0.28														0.28			
Sioux City, Iowa.	3	4:15 p. m.	5:40 p. m.	1.51	4:34 p. m.	5:16 p. m.	0.03	0.12	0.24	0.42	0.71	0.94	1.14	1.23	1.37	1.43					
Spokane, Wash.	31			0.05														0.05			
Springfield, Ill.	9	8:16 p. m.	D. N. p. m.	0.80	8:18 p. m.	8:32 p. m.	0.01	0.16	0.40	0.58											
Springfield, Mo.	10	3:10 a. m.	4:48 a. m.	0.84	3:42 a. m.	4:02 a. m.	0.04	0.20	0.45	0.62	0.72										
Syracuse, N. Y.	10	2:55 p. m.	3:30 p. m.	1.27	3:08 p. m.	3:27 p. m.	0.04	0.23	0.52	1.04	1.23										
Tacoma, Wash.	31			0.05														0.04			
Tampa, Fla.	9	4:50 p. m.	5:45 p. m.	1.40	4:53 p. m.	5:31 p. m.	0.01	0.29	0.68	1.03	1.14	1.24	1.29	1.34	1.39						
	20–21	9:45 p. m.	5:30 p. m.	1.93	10:54 a. m.	11:26 a. m.	0.75	0.05	0.17	0.24	0.28	0.40	0.59	0.62							
	28	2:25 p. m.	7:15 p. m.	1.09	4:04 p. m.	4:26 p. m.	0.17	0.15	0.40	0.58	0.69	0.72									
	29	6:25 p. m.	7:20 p. m.	1.44	6:32 p. m.	7:04 p. m.	0.03	0.14	0.43	0.76	1.09	1.27	1.36	1.38							
Tatoosh Island, Wash.	6			0.04														0.04			
Taylor, Tex.	21	8:15 a. m.	6:30 p. m.	1.88	2:12 p. m.	2:45 p. m.	1.01	0.09	0.21	0.34	0.45	0.56	0.60	0.68							
Terre Haute, Ind.	31	3:03 p. m.	3:55 p. m.	0.65	3:20 p. m.	3:32 p. m.	0.02	0.18	0.47	0.52											
Thomasville, Ga.	8	2:26 p. m.	4:59 p. m.	1.70	2:36 p. m.	3:30 p. m.	0.01	0.26	0.59	0.72	0.82	1.04	1.26	1.40	1.44	1.48	1.56	1.64			
	12	5:43 p. m.	8:48 p. m.	1.30	5:49 p. m.	6:35 p. m.	0.01	0.29	0.55	0.76	0.80	0.89	0.99	1.05	1.15	1.20	1.24				
	16	2:15 p. m.	5:10 p. m.	0.81	2:20 p. m.	2:39 p. m.	0.01	0.20	0.38	0.52	0.60										
Toledo, Ohio.	21	7:10 p. m.	7:42 p. m.	0.82	7:13 p. m.	7:38 p. m.	0.01	0.22	0.37	0.51	0.66	0.81									
Tonopah, Nev.	9			0.13														0.13			
Topeka, Kans.	31			0.27														0.12			
Trenton, N. J.	12–13	11:25 p. m.	6:50 a. m.	2.16	2:30 a. m.	3:04 a. m.	0.25	0.05	0.14	0.24	0.27	0.49	0.72	0.92							
					5:21 a. m.	5:49 a. m.	1.32	0.17	0.21	0.30	0.49	0.67	0.73								
	19	1:42 p. m.	3:10 p. m.	0.82	1:46 p. m.	2:26 p. m.	0.01	0.14	0.23	0.28	0.38	0.51	0.59	0.68	0.73						
	20	11:50 a. m.	5:30 p. m.	1.80	1:46 p. m.	2:10 p. m.	0.46	0.45	0.74	0.99	1.12	1.19									
	21	7:58 a. m.	4:30 p. m.	1.08	11:38 a. m.	12:15 p. m.	0.31	0.10	0.21	0.34	0.50	0.52	0.56	0.65	0.76						
Valentine, Nebr.	20			0.41														0.35			
Vicksburg, Miss.	7	6:45 a. m.	D. N. p. m.	0.73	6:50 p. m.	7:10 p. m.	0.01	0.15	0.41	0.50	0.57										
	8	11:08 a. m.	2:15 p. m.	1.28	12:21 p. m.	12:40 p. m.	0.09	0.12	0.35	0.48	0.56										
	16	4:25 a. m.	5:10 a. m.	0.62	4:31 a. m.	4:56 a. m.	0.01	0.15	0.34	0.42	0.50	0.59	0.61								
Walla Walla, Wash.	6			0.05														0.05			
Washington, D. C.	15	6:30 a. m.	9:20 a. m.	0.63	8:05 a. m.	8:22 a. m.	0.01	0.15	0.29	0.48	0.56										
	18	6:48 a. m.	9:50 a. m.	0.88	7:47 a. m.	8:18 a. m.	0.10	0.05	0.15	0.27	0.44	0.60	0.69	0.71							
		5:40 p. m.	9:15 p. m.	1.13	6:19 p. m.	6:52 p. m.	0.01	0.08	0.10	0.15	0.20	0.44	0.74	0.83							
	22	3:35 a. m.	8:40 a. m.	0.79	5:24 a. m.	5:48 a. m.	0.01	0.17	0.38	0.52	0.57	0.61									
Wausau, Wis.	14	D. N. a. m.	5:00 a. m.	1.21	2:27 a. m.	2:47 a. m.	0.01	0.18	0.42	0.69	0.75										
	25	6:29 p. m.	8:20 p. m.	0.80	6:36 p. m.	7:01 p. m.	0.01	0.16	0.32	0.49	0.53	0.65									
Wichita, Kans.	4			0.25														0.22			
Williston, N. Dak.	2	D. N. a. m.	D. N. a. m.	0.62	12:48 a. m.	1:20 a. m.	T.	0.16	0.25	0.31	0.37	0.46	0.58	0.60							
Wilmington, N. C.	14	2:14 p. m.	6:35 p. m.	0.98	2:26 p. m.	3:01 p. m.	0.02	0.09	0.15	0.24	0.35	0.42	0.48	0.55							
	29–30	9:45 p. m.	D. N. a. m.	0.32	9:45 p. m.	11:04 p. m.	0.00	0.17	0.27	0.41	0.49	0.56	0.61	0.65	0.68	0.72	0.74	0.89	1.23		
Winnemucca, Nev.	23			T.														T.			
Wytheville, Va.	16			0.59														0.40			
Yankton, S. Dak.	19			1.06														0.59			
Yellowstone Park, Wyo.	29			0.33														0.15			

* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, July, 1919.*

Stations.	Altitude above mean sea level Jan. 1, 1919.	Pressure.			Temperature.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.+ 2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.72	29.83	−0.14	55.5	− 3.8	64.6	46.5	76	35	4.83	+0.94	.....
Sydney, C. B. I.	48	29.89	29.94	+0.01	62.4	+ 0.1	71.9	52.8	81	43	4.20	+0.65	.....
Halifax, N. S.	88	29.84	29.94	−0.02	64.3	+ 0.9	74.1	54.5	83	43	2.59	−0.46	.....
Yarmouth, N. S.	65	29.88	29.95	0.00	60.4	+ 0.9	68.3	52.5	83	42	4.46	+0.84	.....
Charlottetown, P. E. I.	38	29.87	29.91	+0.01	64.0	− 0.1	72.3	53.7	82	39	3.92	+0.43	.....
Chatham, N. B.	28	29.89	29.91	+0.03	66.6	+ 1.6	77.6	55.6	92	42	2.53	−1.66	.....
Father Point, Que.	20	29.86	29.88	+0.03	56.3	− 1.3	65.1	47.5	84	39	2.57	−0.67	.....
Quebec, Que.	296	29.60	29.92	+0.01	68.2	+ 1.7	78.1	58.4	88	48	8.14	+3.88	.....
Montreal, Que.	187	29.73	29.93	0.00	70.7	+ 2.2	79.5	61.8	91	54	2.00	−2.29	.....
Stonecliffe, Ont.	489	29.33	29.92	−0.02	62.5	− 3.1	85.5	39.5	98	28	1.26	−1.86	.....
Ottawa, Ont.	236	29.68	29.94	0.00	71.7	+ 2.2	83.7	59.8	97	50	1.45	−2.04	.....
Kingston, Ont.	285	29.65	29.95	−0.02	71.0	+ 2.8	78.9	63.2	88	54	1.03	−1.86	.....
Toronto, Ont.	379	29.57	29.96	−0.01	73.3	+ 5.3	84.9	61.6	98	52	3.20	+0.28	.....
Cochrane, Ont.	930	28.92	.....	.....	67.0	.....	79.9	54.1	93	34	4.21	.....	.....
White River, Ont.	1,244	28.64	29.93	−0.01	63.7	+ 4.2	79.4	48.0	93	31	3.27	−0.47	.....
Port Stanley, Ont.	592	29.38	30.01	+0.03	69.9	+ 2.1	80.6	59.1	86	47	1.87	−1.17	.....
Southampton, Ont.	656	29.28	.....	.....	68.8	+ 4.1	80.1	57.5	94	46	1.20	−0.78	.....
Parry Sound, Ont.	688	29.30	29.98	+0.02	70.2	+ 4.2	84.0	56.5	98	46	1.57	−1.05	.....
Port Arthur, Ont.	644	29.25	29.95	+0.01	66.0	+ 4.0	77.2	54.8	92	42	2.58	−0.90	.....
Winnipeg, Man.	760	29.08	29.89	−0.04	69.0	+ 3.0	80.9	57.1	90	45	3.83	+0.75	.....
Minnedosa, Man.	1,690	28.12	29.89	−0.04	66.6	+ 4.4	80.6	52.7	98	42	1.13	+1.47	.....
Le Pas, Man.	860	28.90	.....	.....	64.5	.....	75.0	54.1	90	47	2.86	.....	.....
Qu'Appelle, Sask.	2,115	27.68	29.88	−0.04	66.1	+ 2.6	80.1	52.2	92	39	2.88	+0.40	.....
Medicine Hat, Alb.	2,144	27.62	27.84	−0.06	72.4	+ 4.6	88.3	56.8	103	47	0.99	−0.10	.....
Moose Jaw, Sask.	1,759	28.00	.....	.....	70.5	.....	86.8	54.2	101	41	1.29	.....	.....
Swift Current, Sask.	2,392	27.35	29.89	−0.02	69.2	+ 2.7	85.7	52.8	103	40	0.66	−1.78	.....
Calgary, Alb.	3,428	26.43	29.88	−0.02	64.3	+ 3.7	81.4	47.3	97	41	1.64	−1.04	.....
Banff, Alb.	4,521	25.42	29.90	0.00	59.0	+ 2.4	76.7	41.4	92	32	1.31	−1.93	.....
Edmonton, Alb.	2,150	27.60	29.85	−0.05	61.9	+ 1.3	74.9	49.0	87	37	2.41	−0.62	.....
Prince Albert, Sask.	1,450	28.32	29.87	−0.04	65.2	+ 3.3	78.6	51.9	94	44	2.02	−0.03	.....
Battleford, Sask.	1,592	28.14	28.84	−0.06	66.3	+ 1.6	81.5	51.2	103	42	0.28	−2.06	.....
Kamloops, B. C.	1,262	28.72	29.98	+0.04	70.4	+ 1.9	86.1	54.7	102	48	1.27	−0.34	.....
Victoria, B. C.	230	29.80	30.05	0.00	58.5	− 1.5	66.4	50.6	84	47	0.02	−0.38	.....
Barkerville, B. C.	4,180	25.77	30.04	+0.13	53.3	− 1.8	65.5	41.2	78	33	3.13	+0.11	.....
Triangle Island, B. C.	680	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Prince Rupert, B. C.	170	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Dawson	.....	28.77	.....	.....	60.0	.....	73.6	46.5	87	40	2.41	.....	.....
Hamilton, Ber.	151	30.04	30.20	+0.06	78.0	− 0.7	83.5	72.4	88	67	0.84	−3.60	.....

SEISMOLOGY.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., Sept. 2, 1919.]

TABLE 1.—*Noninstrumental earthquake reports, July, 1919.*

Day.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
	H. m.	CALIFORNIA.	° ′	° ′			*Sec.*			
July 13	12 13½	Corona	33 52	117 35	2	1	2 or 3	None	Felt by several	Thomas C. Sias.
20	4 15	Oak Grove	33 26	116 51	5	1	2	Loud	Felt by many	A. J. Berg.
31	21 30	Idria	36 24	120 42	3	2	1	None	Felt by several	O. M. Sherburne.
		KANSAS.								
26	12 55	Wichita	37 41	97 20	4	2	2	Loud rumbling	Felt by several	Mrs. J. B. Daze.

TABLE 2.—*Instrumental seismological reports, July, 1919.*

(Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.)

[For significance of symbols see REVIEW for January, 1919, p. 59.]

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Alabama. *Mobile. Spring Hill College.* Earthquake Station. Cyril Ruhlmann, S. J.

Lat., 30° 41′ 44″ N.; long., 88° 08′ 46″ W. Elevation, 60 meters.

Instrument: Wiechert 80 kg.; astatic, horizontal pendulum.

(Report for July, 1919, not received.)

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants.		V	T_0
	E	10	17.7
	N	10	16.6

(No earthquake recorded during July, 1919.)

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Wm. H. Cullum.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants.		V	T_1
	E	10	15
	N	10	18

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodeti Survey. Wm. H. Cullum.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants.		V	T_0
	E	10	14
	N	10	18

1919.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July	1	P_N	21 55 16					
		eP_E	21 55 22					
		L_N	21 57 21					
		M_N	21 57 32	8		10		
		C_N	21 57 48					
		F_E	21 59 ..					
		F_N	22 00 ..					
	6	P_N	7 09 22					
		S_N	7 13 33					
		eL_N	7 16 38					
		P_E	7 20 33					
		C_N	7 21 ..					
		F_E	7 28 ..					
		F_N	7 32 ..					
	9	eP_N	19 23 14					eP_N faint.
		eS_E	19 27 14					
		S_N	19 27 20					
		eL_E	19 28 50					
		eL_N	19 29 51					
		M_N	19 30 14					
		C_N	19 33 55	5				
		F_E	19 35 ..					
		F_N	19 41 ..					

Period of pendulum: E. 17 sec., N. 20 sec.

TABLE 2.—*Instrumental seismological reports July, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
California. *Berkeley. University of California.* Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters. (*See* Bulletin of the Seismographic Stations, University of California.)								
California. *Mount Hamilton. Lick Observatory.* Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters. (*See* Bulletin of the Seismographic Stations, University of California.)								
California. *Point Loma. Raja Yoga Academy.* F. J. Dick. Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters. Instrument: Two-component, C. D. West seismoscope.								
1919. July	3			*H. m. s.*	*Sec.*	μ 50	μ 50	*Km.*
	15					100	100	
California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J. Lat., 37° 26′ 36″ N.; long., 121° 57′ 63″ W. Elevation, 27.43 meters. (*See* Record of the Seismographic Station. University of Santa Clara.)								
Colorado. *Denver. Sacred Heart College.* Earthquake Station. A. W. Forstall, S. J. Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters. Instrument: Wiechert 80 kg., astatic, horizontal pendulum. (*No earthquakes reported for July, 1919.*)								
District of Columbia. *Washington. U. S. Weather Bureau.* Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters. Instrument: Marvin (vertical pendulum), undamped. Mechanical registration. Instrumental constants.. V 110 T_0 6.4								
1919. July 6		P	*H. m. s.* 7 10 ca.	*Sec.*			*Km.* 3540?	Time correction uncertain.
		S	7 15 20ca					
		L	7 19 30ca	25				
		F	7 50					
8		P	21 25 15					
		S	21 34 48					
		L	21 56 ..	28				
		L	22 05 ..	20				
		L	22 10 ..	18				
		F	22 40 ..					
9		P?	19 26 16				3700?	
		S	19 31 45					
		L	19 38 10	12				
		F	20 30 ..					
10		e	2 42 40					
		F	2 52 ..					
11		P	0 36 57					
		S	0 44 00					
		eL	0 50 45					
		F	1 15 ..					
14		eL	14 26 20	16				
		F	14 45 ..					
17		P	16 25 57				3280	
		S	16 31 00					
		L	16 35 50	20				
		L	16 40 ..	14				
		F	16 50 ..					
18		e?	13 43 50					
		L	13 58 00					
		F	14 10 ..					
22		iP	22 07 10				2920	
		iS	22 11 47					
		LT	22 14 20					
		F	22 30 ..					
24		e	2 27 56					
		F	2 32 ..					
25		e	19 05 00					
		S?	19 09 14					
		F	19 30 ..					
31		eP	22 02 42				8220	
		S	22 12 13					
		F	22 30 ..					

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
District of Columbia. *Washington. Georgetown University.* F. A. Tondorf, S. J. Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite. Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical. Instrumental constants.. E: V 165, T_0 5.4, ϵ 0; N: 143, 5.2, 0; Z: *80*, *5.0*, *0*								
1919. July 1		e_E	*H. m. s.* 21 36 27	*Sec.*	μ	μ	*km.*	
		eL_E	21 49 30					
		eL_N	21 49 36					
		F	22 46 ..					
6		eP_N	7 10 05					
		eP_E	7 10 15					
		S	7 15 35					
		eL	7 18 30	10				
		F	7 50 ..					
			Vertical.					
		eP	*7 10 04*					
		S	*7 15 35*					
		F	*8 00* ..					
7		e_E	14 48 ..					N–S does not show, microseisms.
		F	15 20 ..					
8		e	21 25 52					Heavy microseisms
		eS_E?	21 34 42					
		eL_E	21 47 ..	11				
		eL_N	21 47 06	11				
		F	23 25 ..					
9		e	19 26 ..					Do.
		eS_N?	19 31 40					
		eL_E	19 38 ..	11				
		eL_N	19 38 ..	15				
		L_N	19 42 ..	11				
		L_E	19 43 ..	9				
		F	20 15 ..					
10		e_N	2 41 26					Microseisms.
		e_E	2 41 30					
		L_N	2 44 19	10				
		F	3 (ca.)					
11		e	0 37 ..					Do.
		S_E?	0 42 12					
		S_N?	0 42 13					
		eL	0 44 30	8				
		F	1 30 ..					
14		e_E?	14 16 17					
		e_N?	14 16 28					
		eL	14 26 36	12				
		F	14 48 ..					
17		iP	16 25 58					
		eS	16 31 04					
		eL	16 36 00	16				
		L_E	16 41 ..	14				
		L_N	16 41 ..	11				
		F	16 55 ..					
22		iP_N	22 07 12					
		iP_E	22 07 13					
		S	22 11 48					
		eL	22 13 48	6				
		F	22 55 ..					
		iP	*22 07 11*					
		S	*22 11 53*					
		eL	*22 13 50*					
		F	*22 35* ..	6				
25		e_E	17 13 ..					Does not show on N–S component.
		F	17 21 ..					
31		e_E?	22 05 43					Heavy microseisms.
		S_E?	22 12 16					Does not show on N–S component.
		F	22 27 ..					

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant.. T_0 18.1. Sensitiveness 0.40 arc tilt=1 mm.

(Report for July not received.)

TABLE 2.—*Instrumental seismological reports, 1919*—Continued.

Illinois. *Chicago. University of Chicago.* U. S. Weather Bureau.

Lat., 41° 47′ N.; long., 87° 37′ W. Elevation, 180.1 meters.

Instruments: Two Milne-Shaw horizontal pendulums, 0.45 kg.

Instrumental constants: Sensitivity.

		V	T_0	ε	
E	150	12	20:1	1″ arc tilt=26.6 mm.
N	150	8	20:1	1″ arc tilt=13.2 mm.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
July 1	.....	e	17 21 30	.....	.....	.....	.....	
		L	17 29 15	15	.....	.....	.....	
		F	17 50 ca	.....	.....	.....	.....	
1	.....	P	21 36 26	.....	.....	.....	2,990	
		S	21 41 08	.....	.....	.....	.....	
		L?	21 43 50	.....	.....	.....	.....	
		F	22 30 ..	.....	.....	.....	.....	
2	.....	e	8 08 18	.....	.....	.....	.....	
		eL	8 14 ..	.....	.....	.....	.....	
		L	8 16 ..	15	.....	.....	.....	
		F	8 45 ..	.....	.....	.....	.....	
4	.....	e	8 39 07	.....	.....	.....	.....	
		L	8 46 ..	18	.....	.....	.....	
		F	9 10 ..	.....	.....	.....	.....	
6	.....	P	7 09 55	.....	.....	.....	3,300	
		iS	7 15 ..	.....	.....	.....	.....	
		L	7 18 10	26	.....	.....	.....	
		F	8 40 ..	.....	.....	.....	.....	
7	.....	eL	14 47 ..	.....	.....	.....	.....	May not be seismic.
		L	14 50 ..	24	.....	.....	.....	
		L	14 56 ..	18	.....	.....	.....	
		F	15 30 ..	.....	.....	.....	.....	
8	.....	P	21 26 00	.....	.....	.....	8,800	
		S	21 36 ..	.....	.....	.....	.....	
		eL	21 51 ..	.....	.....	.....	.....	
		L	22 03 ..	26	.....	.....	.....	
		M_E	22 12 ..	.....	*600	.....	.....	
		L	22 14 ..	20	.....	.....	.....	
		L	22 22 ..	15	.....	.....	.....	
9	.....	F	0 30 ..	.....	.....	.....	.....	
9	.....	P	19 25 38	.....	.....	.....	3,200	
		iS	19 30 30	.....	.....	.....	.....	
		L	19 33 15	10	.....	.....	.....	
		M_E	19 37 30	.....	*2,500	.....	.....	
		F	20 40 ..	.....	.....	.....	.....	
10	.....	e	2 37 28	.....	.....	.....	.....	
		F	3 15 ..	.....	.....	.....	.....	
11	.....	iP	0 37 50	.....	.....	.....	3,875	
		iS	0 43 30	.....	.....	.....	.....	
		SR_1	0 46 15	.....	.....	.....	.....	
		L	0 48 08	24	.....	.....	.....	
		L	0 54 ..	20	.....	.....	.....	
		M	0 55 ..	.....	*200	.....	.....	
		F	1 50 ..	.....	.....	.....	.....	
11	.....	P	4 16 43	.....	.....	.....	.....	
		S	4 22 30	.....	.....	.....	.....	
		SR_1	4 25 15	.....	.....	.....	.....	
		L	4 30 30	15	.....	.....	.....	
		F	4 55 ..	.....	.....	.....	.....	
12	.....	P?	22 35 45	.....	.....	.....	.....	
		S?	22 41 38	.....	.....	.....	.....	
		L	22 47 30	15	.....	.....	.....	
		F	23 20 ..	.....	.....	.....	.....	
14	.....	L	14 25 ..	15	.....	.....	.....	Beginning not recorded. Adjusting instrument.
		F	15 40 ..	.....	.....	.....	.....	
16	.....	e	18 51 ..	.....	.....	.....	.....	
		L	18 58 ..	15	.....	.....	.....	
		F	19 50 ..	.....	.....	.....	.....	
17	.....	eL	10 48 ..	.....	.....	.....	.....	
		F	11 20 ..	.....	.....	.....	.....	
17	.....	P	16 26 05	.....	.....	.....	3,300	
		S	16 31 10	.....	.....	.....	.....	
		L	16 38 ..	16	.....	.....	.....	
		F	17 30 ..	.....	.....	.....	.....	
18	.....	eL	2 53 ..	16	.....	.....	.....	
		F	3 05 ..	.....	.....	.....	.....	
18	.....	P	13 42 44	.....	.....	.....	3,630	
		S	13 48 10	.....	.....	.....	.....	
		L	13 53 10	.....	.....	.....	.....	
		F	14 45 ..	.....	.....	.....	.....	
20	.....	P?	8 30 20	.....	.....	.....	.....	
		S?	8 35 13	.....	.....	.....	.....	
		L	8 38 15	16	.....	.....	.....	
		F	8 55 ..	.....	.....	.....	.....	

* Trace amplitude.

Illinois. *Chicago. University of Chicago.*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
22	.....	iP	22 07 14	.....	.....	.....	2,930	
		PR_1	22 08 44	.....	.....	.....	.....	
		iS	22 11 52	.....	.....	.....	.....	
		L	22 14 30	15	.....	.....	.....	
		F	23 20 ..	.....	.....	.....	.....	
24	.....	P	2 27 41	.....	.....	.....	5,870?	
		S?	2 35 10	.....	.....	.....	.....	
		L?	2 46 40	25	.....	.....	.....	
		L	2 59 ..	16	.....	.....	.....	
		F	4 10 ..	.....	.....	.....	.....	
24	.....	P?	4 52 18	.....	.....	.....	.....	
		S?	4 58 04	.....	.....	.....	.....	
		L?	5 02 20	.....	.....	.....	.....	
		F	5 50 ..	.....	.....	.....	.....	
25	.....	P	19 03 10	.....	.....	.....	3,840	
		S	19 08 48	.....	.....	.....	.....	
		L?	19 14 45	.....	.....	.....	.....	
		F	20 00 ..	.....	.....	.....	.....	
31	.....	P?	7 29 15	.....	.....	.....	.....	
		S?	7 35 40	.....	.....	.....	.....	
		L	7 48 ..	18	.....	.....	.....	
		L	7 57 56	22	.....	.....	.....	
		L	8 10 ..	15	.....	.....	.....	
		F	9 30 ..	.....	.....	.....	.....	
31	.....	P	22 01 11	.....	.....	.....	5,770	
		S	22 08 35	.....	.....	.....	.....	
		eL?	22 18 ..	.....	.....	.....	.....	
		F	22 40 ..	.....	.....	.....	.....	

Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Wiechert.

Instrumental constants:

	V	T_0	ε
E	177	3.4	4:1
N	205	3.4	4:1

(Report for July, 1919, not received.)

Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants:

	V	To
E	10	15
N	10	15

1919 Date.	Character.	Phase.	*H. m. s.*	*Sec.*	μ	μ	*km.*	Remarks.
July 6	.....	eP_E	7 10 15	.....	.....	.....	.....	First appearance of long waves rather abrupt.
		eP_N	7 10 30	.....	.....	.....	.....	
		S_N	7 15 00	.....	.....	.....	.....	
		S_E	7 15 17	.....	.....	.....	.....	
		L_E	7 20 49	.....	.....	.....	.....	
		L_N	7 20 56	.....	.....	.....	.....	
		M_E	7 21 20	10	40	.....	.....	
		M_N	7 22 30	9	.....	50	.....	
		C_N	7 24 ..	.....	.....	.....	.....	
		C_E	7 26 ..	.....	.....	.....	.....	
		F_N	7 35 ..	.....	.....	.....	.....	
		F_E	7 37 ..	.....	.....	.....	.....	
8	.....	eL_N	21 59 00	.....	.....	.....	.....	L_N is faint until 22:07.
		eL_E	22 01 50	24	.....	.....	.....	
		L_N	22 07 00	.....	.....	.....	.....	
		M_E	22 07 04	20	50	.....	.....	
		M_N	22 10 40	17	.....	.....	.....	
		M_N	22 15 50	17	.....	.....	.....	
		C_E	22 15 ..	18	.....	.....	.....	
		F_N	22 21 ..	.....	.....	.....	.....	
		F_E	22 26 ..	18	.....	.....	.....	
9	.....	eP_N	19 31 41	.....	.....	.....	.....	E–W not in operation.
		L_N	19 38 17	14	.....	.....	.....	
		M_N	19 39 00	12	.....	80	.....	
		C_N	19 39 55	9	.....	.....	.....	
		F_N	19 58 ..	8	.....	.....	.....	

TABLE 2.—*Instrumental seismological reports, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Maryland. *Cheltenham. Magnettic Observatory*—Continued.								
1929 July 17	.....	eP_E	*H. m. s.* 16 30 42	*Sec.*	μ	μ	*km.*	
		eP_N	16 31 11					
		L_N	16 35 55					
		L_E	16 36 42					
		M_N	16 39 00	15	10			
		C_N	16 42 40	13				
		F_E	16 43 ..					
		F_N	16 47 ..					
18	.....	L_N	13 57 50					
		L_E	13 58 35					
		M_N	14 00 20	11		10		
		M_E	.. .. ..		10			
		C_N	14 02 30	8				
		F_E	14 07 ..					
		F_N	14 09 ..					
22	.....	P_N	22 07 21	3				
		P_E	22 07 25	4				
		S_N	22 11 57	5				
		S_E	22 11 57					
		eL_N	22 14 00					
		L_E	22 14 06					
		M_E	22 14 36	8	30			
		C_E	22 16 15	6				
		M_N	22 23 45			10		
		F_E	22 25 ..					
		F_N	22 28 ..					
31	.....	iP_E	22 12 43	4				
		iP_N	22 12 45	4				
		eL_N	22 16 05					
		M_E	.. .. ..		10			
		F_E	22 17 ..					
		F_N	22 19 ..					

Period of pendulum: E. 15 sec., N. 15 sec

Massachusetts. *Cambridge. Harvard University Seismographic Station.* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial. sand over clay.

Instruments: T wo Bosch-Omori 100 kg. horizontal pendulums (mechanical registration

Instrumental constants..		V	T_0	e
	E	80	23	0
	N	50	25	4:1

(Report for July, 1919, nor received.)

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12) feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert 80 kg. astatic, horizontal pendulum.

Instrumental constants..	V	T_0	e
	80	7	5:1

(Report for July, 1919, not received.)

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration)

Instrumental constants..		V	T_0	e
	E	13	22	4:1
	N	14	25	4:1

(Report for July, 1919, not received.)

New York. *New York. Fordham University.* W. C. Repetti, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants..		V	T_0	e
	E	72	5.0	0
	N	72	5.0	0

(Report for July, 1919, not received.)

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Panama Canal Zone. *Balboa Heights.* Governor, Panama Canal.								
1914. July 10	.....	P_E	*H. m. s.* 19 32 44	*Sec.*	μ	μ	*km.* 825	Direction uncertain.
		P_N	19 33 04					
		S_N	19 34 04					
		S_E	19 34 08					
		L_N	19 34 44	20				
		L_E	19 34 48	20				
		M_N	19 34 59			*5,000		
		M_E	19 36 28		*3,500			
		F	19 53					
11	.....	M_E	4 11 35	20				Trace, indistinct.
		M_N	4 13 13	20				
		F	4 20 ..					
17	.....	P_E	16 22 04				1,140	Direction uncertain.
		P_N	16 22 14					
		S_E	16 23 52					
		L_E	16 25 32	20				
		L_N	16 25 36	20				
		M_N	16 25 44			*1,200		
		M_E	16 25 50		*1,000			
		F_N	16 33 ..					
		F_E	16 33 24					
22	.....	P_E	22 02 24				685	
		P_N	22 02 26					
		L_E	22 02 26	20				
		L_N	22 03 54	20				Do.
		M_E	22 02 37		*2,200			
		M_N	22 04 02			*1,800		
		F_E	22 13 ..					
		F_N	22 14 ..					

*Trace amplitude.

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. W. M. Hill.

Lat., 18° 09′ N.; long., 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants..		V	T_0
	E	10	17
	N	10	19

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919. July 6	.....	eP_E	*H. m. s.* 7 13 05	*Sec.*	μ	μ	*Km.*	
		L_N	7 16 18					
		eL_E	7 18 15					
		M_N	7 16 34			10		
		M_E	.....		10			
		F_N	7 22 ..					
		F_E	7 25 ..					
8	.....	eL_E	21 54 10					Not recognizable on N component.
		M_E	21 59 10	20	20			
		C_E	22 01 15	20				
		F_E	22 09 ..					
11	.....	eP_N	0 35 57					Both P and L difficult. Only a trace on N component.
		eP_E	0 36 31					
		L_E?	0 37 38					
		L_E	0 38 48					
		M_E	0 38 58	19	10			
		C_E	0 41 ..					
		F_E	0 45 ..					
		F_N	0 50 ..					
17	.....	P_E?	16 27 50					P faint and difficult. No trace on N component.
		L_E	16 35 43					
		M_E	16 36 53	17	10			
		C_E	16 40 ..	14				
		F_E	16 45 ..					
22	.....	iP_N	22 06 06					No long waves on N component.
		IP_E	22 06 08					
		L_E	22 10 48					
		M_E	22 12 43	13	10			
		C_E	22 14 ..					
		F_N	22 13 ..					
		F_E	22 21 ..					

Period of pendulum: E. 17 sec., N. 20 sec.

TABLE 2.—*Instrumental seismological reports, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. Aa	Amplitude. An	Distance.	Remarks.
Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.								
Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.								
Instruments: Two Bosch-Omori, mechanical registration.								
Instrumental constants..				V	T0			
				E	10	15		
				N	10	16		
1919.			*H. m. s.*	*Sec.*			*Km.*	
July 6	.....	e.....	7 12 10	.....	.....	.....	.....	
	.....	L.....	7 18 30	.....	.....	.....	.....	
	.....	F?....	7 30 ..	.....	.....	.....	.....	
9	.....	eL....	19 43 ..	.....	.....	.....	.....	
	.....	F.....	20 00 ..	.....	.....	.....	.....	
22	.....	P.....	22 08 01	.....	.....	.....	3,540	
	.....	S.....	22 13 21	.....	.....	.....	.....	
	.....	eL?...	22 17 ..	.....	.....	.....	.....	
	.....	F.....	22 25 ..	.....	.....	.....	.....	
31	.....	e.....	22 10 50	.....	.....	.....	.....	
	.....	F.....	22 17 ..	.....	.....	.....	.....	
Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.								
Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.								
Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoye 80 kg. vertical seismograph.								
Instrumental constants..				V	T0			
				120	26			
1919.			*H. m. s.*	*Sec.*			*Km.*	
July 1	.....	e.....	21 37 35	.....	.....	.....	.....	Amplitudes small. Note small periods on the L waves.
	.....	i.....	21 43 16	.....	.....	.....	.....	
	.....	eL?...	21 52 40	.....	.....	.....	.....	
	.....	L.....	21 54 12 to 22 22 ...	8 to 7.5	.....	.....	.....	
	.....	F.....	22 40...	.....	.....	.....	.....	
2	.....	e?N....	7 54...	.....	.....	.....	.....	
	.....	eN.....	8 09 30	.....	.....	.....	.....	
	.....	eL?...	8 14...	7	.....	.....	.....	
	.....	L.....	8 18...	17	.....	.....	.....	
	.....	L.....	8 30...	8	.....	.....	.....	
	.....	F.....	8 45...	.....	.....	.....	.....	
6	.....	O.....	7 04 17	.....	.....	.....	3460	
	.....	P.....	7 10 54	.....	.....	.....	.....	
	.....	S.....	7 16 08	.....	.....	.....	.....	
	.....	eLE....	7 19 24	22	.....	.....	.....	
	.....	L.....	7 25...	20	.....	.....	.....	
	.....	L.....	7 45...	8	.....	.....	.....	
	.....	F.....	8 15...	.....	.....	.....	.....	
7	.....	eL....	14 50 to 15 00	.....	.....	.....	.....	
8	.....	0?....	21 13 42	.....	.....	.....	(8080)	
	.....	iP?...	21 25 04	.....	.....	.....	.....	
	.....	e?.....	21 31 54	.....	.....	.....	.....	
	.....	eS?....	21 34 30	10	.....	.....	.....	
	.....	e.....	21 40 24	.....	.....	.....	.....	
	.....	eL?N...	21 55...	.....	.....	.....	.....	
	.....	eL....	21 58...	35	.....	.....	.....	
	.....	L.....	22 10...	18	.....	.....	.....	
	.....	L.....	22 21...	16	.....	.....	.....	
	.....	LN....	22 41...	17	.....	.....	.....	
	.....	L.....	23 03 ...	15	.....	.....	.....	After 23 hours the amplitudes are so small as to be barely readable.
	.....	F.....	23 40...	.....	.....	.....	.....	
9	.....	i.....	19 28 16	.....	.....	.....	.....	End of record very faintly marked, irregular periods.
	.....	i.....	19 32 44	.....	.....	.....	.....	
	.....	iN....	19 35 34	.....	.....	.....	.....	
	.....	eL?...	19 39 48	.....	.....	.....	.....	
	.....	L.....	19 42...	9	.....	.....	.....	
	.....	L.....	20 00...	8	.....	.....	.....	
	.....	F.....	20 30...	.....	.....	.....	.....	
10	.....	eL?N...	2 38 48	.....	.....	.....	.....	
	.....	L.....	2 40 30	8	.....	.....	.....	
	.....	L.....	2 44...	8	.....	.....	.....	
	.....	F.....	3 05...	.....	.....	.....	.....	
11	.....	iN....	0 38 11	.....	.....	.....	.....	Very irregular. Wind tremors make record difficult to read.
	.....	iN....	0 39 33	.....	.....	.....	.....	
	.....	i.....	0 44 20	.....	.....	.....	.....	
	.....	eL?...	0 50 30	.....	.....	.....	.....	
	.....	L.....	0 58...	15	.....	.....	.....	
	.....	F.....	1 20...	.....	.....	.....	.....	

Date.	Character.	Phase.	Time.	Period T.	Amplitude. Aa	Amplitude. An	Distance.	Remarks.
Canada. *Ottawa. Dominion Astronomical Observatory*—Continued.								
1919.			*H. m. s.*	*Sec.*			*Km.*	
July 12	.....	e.....	22 38 30	.....	.....	.....	.....	Very small amplitudes; barely discernible.
	.....	eL....	22 43 30	18	.....	.....	.....	
	.....	F.....	22 55...	.....	.....	.....	.....	
14	.....	eL?...	14 16....	28	.....	.....	.....	No indication of P. or S. Local blasting interferes on NS during this record.
	.....	L.....	14 25 ...	15	.....	.....	.....	
	.....	F.....	14 50....	.....	.....	.....	.....	
17	.....	L.....	10 52 to 11 10...	16	.....	.....	.....	
17	.....	O.....	16 19 46	.....	.....	.....	3,840	
	.....	iPN....	16 26 52	.....	.....	.....	.....	
	.....	PR1N...	16 28 04	.....	.....	.....	.....	
	.....	PR2N...	16 28 24	.....	.....	.....	.....	
	.....	S.....	16 32 40	.....	.....	.....	.....	
	.....	eL....	16 38....	.....	.....	.....	.....	
	.....	L.....	16 40....	23	.....	.....	.....	
	.....	F.....	17 00....	.....	.....	.....	.....	
22	.....	O.....	22 01 25	.....	.....	.....	3,500	
	.....	iP?....	22 08 05	.....	.....	.....	.....	
	.....	i.....	22 08 37	.....	.....	.....	.....	
	.....	e.....	22 09 10	.....	.....	.....	.....	
	.....	iS?....	22 13 22	.....	.....	.....	.....	
	.....	e.....	22 14 20	.....	.....	.....	.....	
	.....	i.....	22 16 06	.....	.....	.....	.....	
	.....	eL?...	22 17 30 to 22 25...	6	.....	.....	.....	
	.....	F.....	22 40....	.....	.....	.....	.....	
24	.....	eN.....	2 16 38	.....	.....	.....	.....	
	.....	eN.....	2 20 24	.....	.....	.....	.....	
	.....	eN.....	2 27 12	.....	.....	.....	.....	
	.....	eL?E...	2 45 30	.....	.....	.....	.....	
	.....	LE....	2 50....	.....	.....	.....	.....	
	.....	L.....	2 55 ...	23	.....	.....	.....	
	.....	L.....	3 00 ...	18	.....	.....	.....	
	.....	L.....	3 05....	.....	.....	.....	.....	
31	.....	e.....	22 05 12	.....	.....	.....	.....	May not be seismic.
	.....	iN....	22 06 17	.....	.....	.....	.....	
	.....	e.....	22 09 24	.....	.....	.....	.....	
	.....	eL?...	22 12 00	.....	.....	.....	.....	
	.....	F.....	22 25....	.....	.....	.....	.....	
Canada. *Toronto. Dominion Meteorological Service.*								
Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.								
Instrument: Milne horizontal pendulum, North; in the meridian.								
Instrumental constant..18.				T0	Pillar deviation, 1 mm. swing of boom=0.45″.			
1919.			*H. m. s.*					
July 1	.....	L.....	21 49 24	.....	*200	.....	.....	Times doubtful.
	.....	L.....	21 58 54	.....		.....	.....	
	.....	F.....	22 23 ..	.....		.....	.....	
2	.....	L.....	8 01 36	.....	*50	.....	.....	
4	.....			.....		.....	.....	Micros after 10h of the 4th to morning of the 5th.
6	.....	P.....	7 11 00?	.....		.....	.....	Micros before P.
	.....	S.....	7 15 36	.....		.....	.....	
	.....	eL....	7 17 36	.....		.....	.....	
	.....	M.....	7 23 54	.....	*200	.....	.....	
	.....	F.....	7 38 30	.....		.....	.....	
7	.....	L?....	14 57 30?	.....		.....	.....	
	.....	eL....	15 00 54	.....		.....	.....	
	.....	M.....	15 04 54	.....	*200	.....	.....	Gradual thickening.
	.....	F.....	15 12 54	.....		.....	.....	
8	.....	iL....	22 01 00	.....		.....	.....	
	.....	eL....	22 10 42	.....		.....	.....	Earlier phases masked by heavy micros.
	.....	M.....	22 16 06	.....	*5,000	.....	.....	
	.....	F.....	Micros.	.....		.....	.....	Lost in microseisms.
9	.....			.....		.....	.....	Heavy micros going on when quake was recorded at other stations.

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. Aa	Amplitude. An	Distance.	Remarks.
Canada. *Toronto. Dominion. Meteorological Service*—Continued.								
10	.....	L.....	2 40 30	.....	*200	.....	.....	Micros going on.
11	.....	L.....	0 46 18	.....	.....	.....	.....	
		L.....	0 49 00	.....	.....	.....	.....	
		M.....	0 56 18	.....	*100	.....	.....	
		F.....	1 26 30	.....	.....	.....	.....	
12	.....	L.....	22 42 06	.....	*100	.....	.....	Small micros going on.
14	.....	e.....	14 13 54?	.....	.....	.....	.....	
		eL.....	14 23 00	.....	.....	.....	.....	
	.....	eL.....	14 31 48	.....	.....	.....	.....	
		M.....	14 38 30	.....	*200	.....	.....	
		F.....	15 03 30	.....	.....	.....	.....	
17	.....	iP.....	16 26 30	.....	.....	.....	.....	
		iP.....	16 30 24	.....	.....	.....	.....	
		eS.....	16 33 54	.....	.....	.....	.....	
		L.....	16 39 24	.....	.....	.....	.....	
		L.....	16 40 36	.....	.....	.....	.....	
		M.....	16 48 42	.....	*300	.....	.....	
		F.....	.....	.....	*	.....	.....	
18	.....	e(or)L	13 25 00?	.....	.....	.....	.....	Small quake $13^h\ 40^m\ 36^s$, phases interfered with, while inspecting instrument.
22	.....	P.....	22 08 06?	.....	.....	.....	.....	
		iP.....	22 11 30	.....	.....	.....	.....	
		S.....	22 14 00	.....	.....	.....	.....	
		eL.....	22 19 48	.....	.....	.....	.....	
		M.....	22 22 12	.....	*200	.....	.....	
		F.....	.....	.....	.....	.....	.....	Lost in microseisms.
24	.....	e.....	2 47 42	.....	.....	.....	.....	
		e.....	2 57 06	.....	.....	.....	.....	
		eL.....	3 01 00	.....	.....	.....	.....	
		M.....	3 02 06	.....	*200	.....	.....	
		eL?...	3 15 48	.....	.....	.....	.....	
		F.....	3 27 18?	.....	.....	.....	.....	
25	.....	L.....	19 13 48?	.....	.....	.....	.....	Marked micros going on.
		L.....	19 19 36	.....	*200	.....	.....	
31	.....	eL.....	8 06 36	.....	.....	.....	.....	
		M.....	{ 8 10 30 / 8 12 24 }	.....	*200	.....	.....	Gradual thickening.
		F.....	8 18 18	.....	.....	.....	.....	
31	.....	L.....	22 05 54	.....	.....	.....	.....	
		L.....	22 12 30	.....	*100	.....	.....	
		F.....	.....	.....	.....	.....	.....	Lost in microseisms.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instrument: Wiechert, vertical; Milne horizontal pendulum, North. In the meridian $\frac{T_0}{18}$. Pillar deviation, 1 mm. swing of boom=0.54″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. Aa	Amplitude. An	Distance.	Remarks.
1919. July 1	.....	P.....	21 50 29	.....	.....	.....	.....	.....
		M.....	21 51 58	.....	*500	.....	.....	
		F.....	22 01 19	.....	.....	.....	.....	
1	.....	P.....	22 05 15	.....	.....	.....	.....	
		L.....	22 06 14	.....	.....	.....	.....	
		M.....	22 07 13	.....	*500	.....	.....	
		F.....	22 12 08	.....	.....	.....	.....	
2	.....	L.....	8 25 12	.....	*50	.....	.....	
		F.....	8 29 36	.....	.....	.....	.....	
6	.....	P?.....	7 15 53	.....	.....	.....	1,940?	
		S.....	7 19 11	.....	.....	.....	.....	
		L.....	7 24 49	.....	.....	.....	.....	
		M.....	7 28 47	.....	*200	.....	.....	
		F.....	7 41 09	.....	.....	.....	.....	

* Trace amplitude.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. Aa	Amplitude. An	Distance.	Remarks.
Canada. *Victoria*, B. C.. *Dominion Met eorological Service*—Contd.								
7	.....	P?.....	14 21 47	.....	.....	.....	.....	
		L.....	14 35 17	.....	.....	.....	.....	
		M.....	14 43 47	.....	*400	.....	.....	
		F.....	14 59 47	.....	.....	.....	.....	
8	.....	.....	.....	.....	.....	.....	.....	Quake missed, light off the paper.
9	.....	P.....	19 35 18	.....	.....	.....	1,410?	
		S?.....	19 37 46	.....	.....	.....	.....	
		L.....	19 38 44	.....	.....	.....	.....	
		M.....	19 01 22	.....	*400	.....	.....	
		F.....	19 48 34	.....	.....	.....	.....	
10	.....	P.....	2 23 03	.....	.....	.....	.....	
		L.....	2 23 33	.....	.....	.....	.....	
		M.....	2 24 02	.....	*300	.....	.....	
		F.....	2 33 23	.....	.....	.....	.....	
11	.....	L?.....	1 06 56	.....	.....	.....	.....	
		M.....	1 14 18	.....	*200	.....	.....	
		F.....	1 30 02	.....	.....	.....	.....	
17		S?.....	16 49 48	.....	.....	.....	.....	
		L.....	16 53 14	.....	.....	.....	.....	
		M.....	16 57 10	.....	*400	.....	.....	
		F.....	17 18 49	.....	.....	.....	.....	
18	.....	P.....	13 38 20	.....	.....	.....	.....	
		M.....	13 40 18	.....	*300	.....	.....	
		F.....	13 45 03	.....	.....	.....	.....	
			Vertical.	.....	***A.***			
	.....	*P.....*	***13 38 16***	*7*	.....	.....	*600*	
		L.....	***13 39 46***	*6*	.....	.....	.....	
		M.....	***13 40 36***	*6*	*7*	.....	.....	
		F.....	***13 49 46***	.....	.....	.....	.....	
22	.....	L?.....	22 35 02	.....	.....	.....	.....	
		M.....	22 38 58	.....	*200	.....	.....	
		F.....	22 42 54	.....	.....	.....	.....	
24	.....	P.....	2 45 16?	.....	.....	.....	.....	
		L.....	2 50 13	.....	.....	.....	.....	
		M.....	3 04 07	.....	*400	.....	.....	
		F.....	3 23 22	.....	.....	.....	.....	
25	.....	L.....	19 16 37?	.....	.....	.....	.....	
		M.....	19 20 35	.....	*400	.....	.....	
		F.....	19 25 03	.....	.....	.....	.....	
31	.....	M.....	7 50 57	.....	*200	.....	.....	
		F.....	8 25 52	.....	.....	.....	.....	
31	.....	L.....	21 58 25	.....	.....	.....	.....	
		M.....	22 00 43	.....	*50	.....	.....	
		F.....	22 06 19	.....	.....	.....	.....	

* Trace amplitude.

SEISMOLOGICAL DISPATCHES.[1]

Guatemala City, Guatemala, July 24, 1919.

A dispatch sent to La Republica, a local paper, states that in the neighborhood of the city of St. Mark, Haiti, a rising of the earth had occurred, forming a small hill. This took place on July 22.

Guatemala City, Guatemala, July 24, 1919.

A communication received to-day at this city reports that on the afternoon of July 22 a strong shock was felt. Also that the Santa Ana volcano had become active. In the Fonseca Bay a small island has appeared.

[1] Reported by the organization indicated and collected by the seismological station at Georgetown University, Washington, D. C.

Chart I. Hydrographs of Several Principal Rivers, July, 1919.

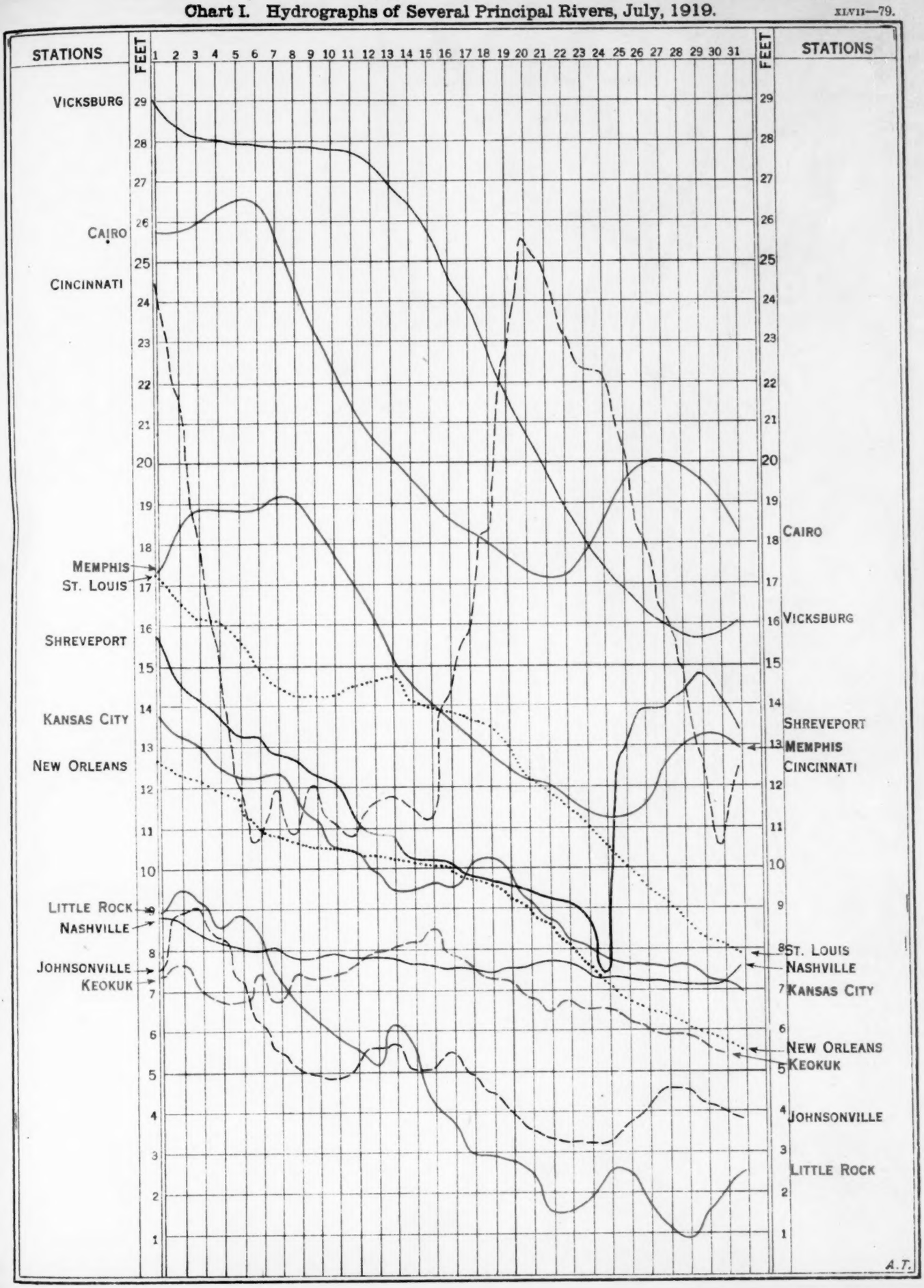


Chart II. Tracks of Centers of High Areas, July, 1919.

(Plotted by R. H. Weightman, Meteorologist.)

Chart III. Tracks of Centers of Low Areas, July, 1919.

(Plotted by R. H. Weightman, Meteorologist.)

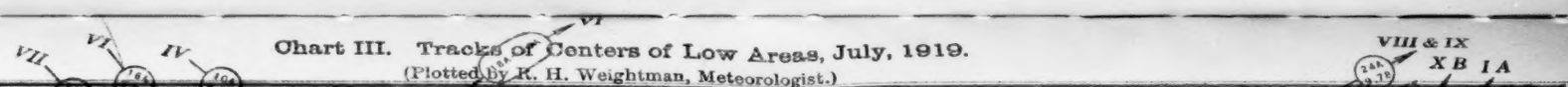


Chart III. Tracks of Centers of Low Areas, July, 1919.

(Plotted by R. H. Weightman, Meteorologist.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, July, 1919.

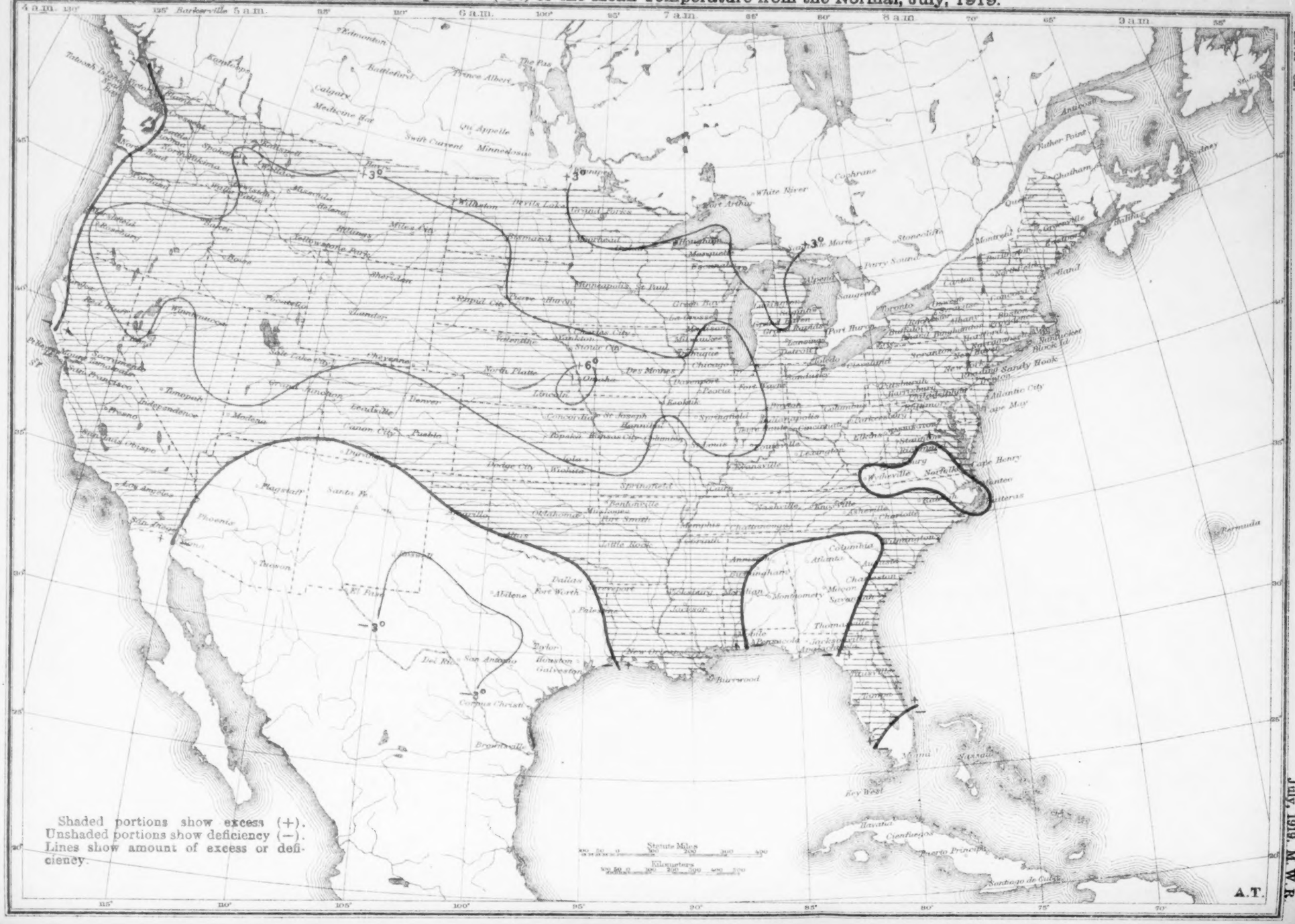


Chart V. Total Precipitation, Inches, July, 1919.

Chart V. Total Precipitation, Inches, July, 1919.

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, July, 1919.

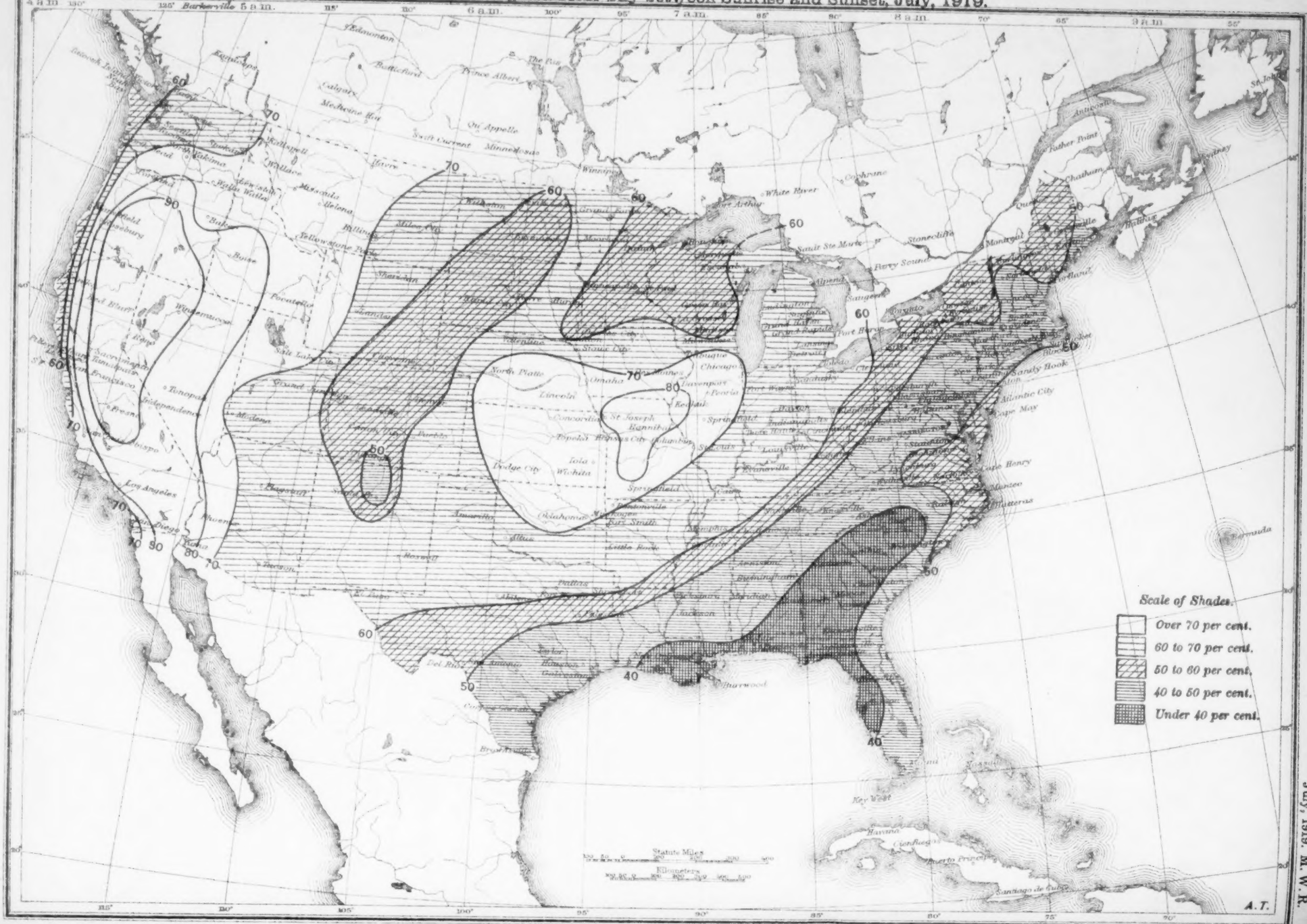


Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, July, 1919.

Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, July, 1919.

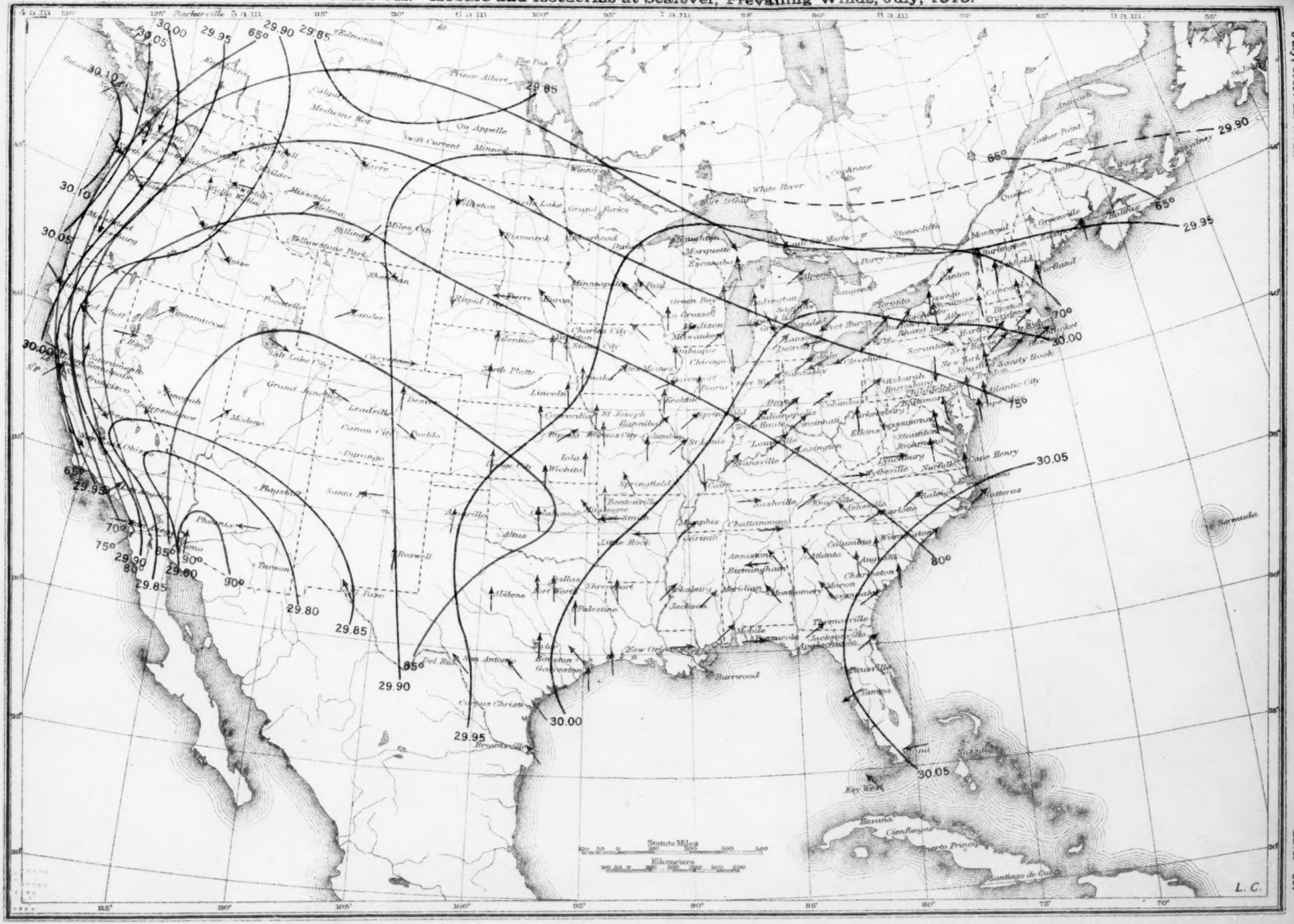
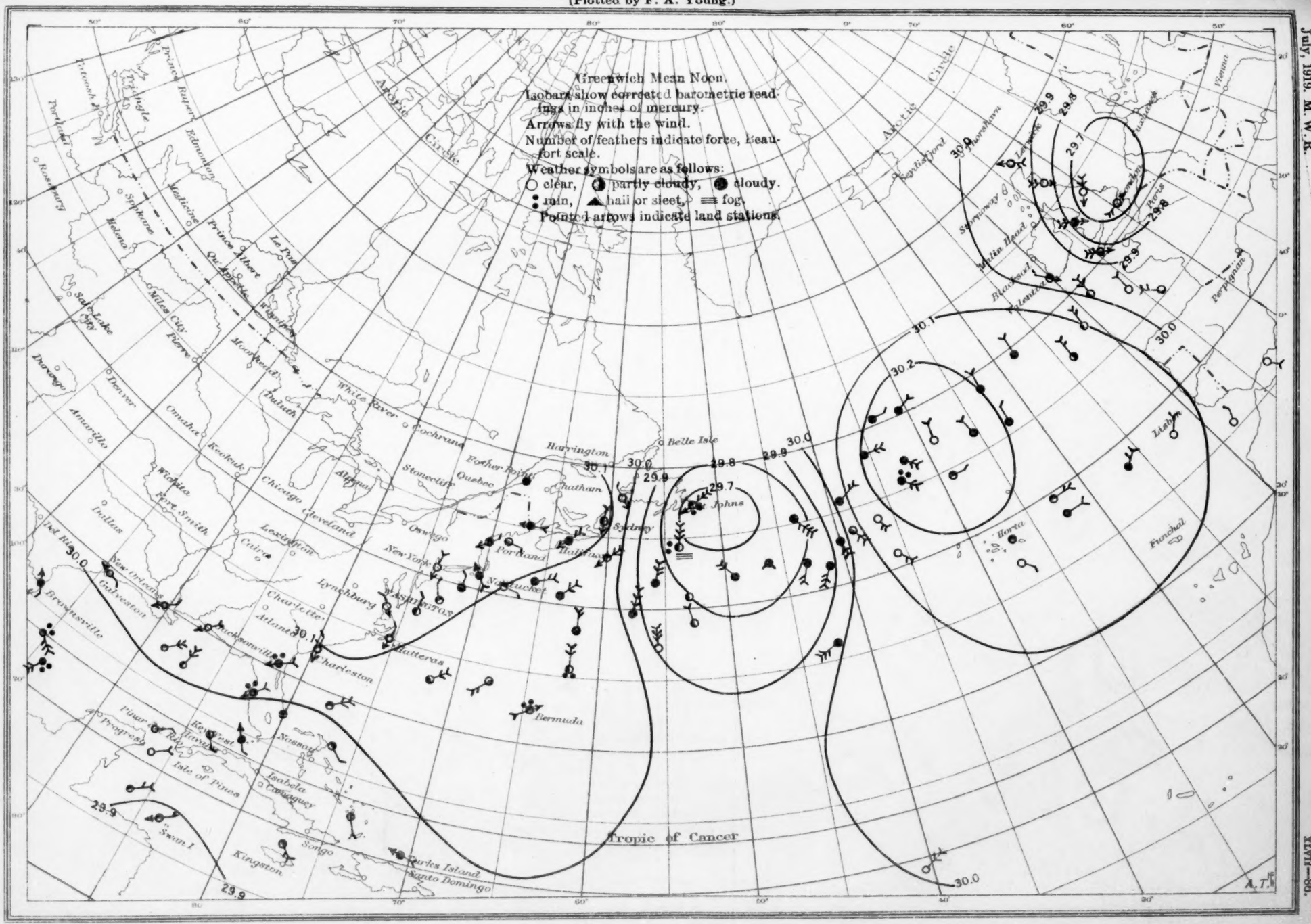


Chart IX. Weather Map of North Atlantic Ocean, July 2, 1919.
(Plotted by F. A. Young.)

Chart IX. Weather Map of North Atlantic Ocean, July 2, 1919.

(Plotted by F. A. Young.)



July, 1919. M. W. R.

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Chart X. Weather Map of North Atlantic Ocean, July 3, 1919.

(Plotted by F. A. Young.)

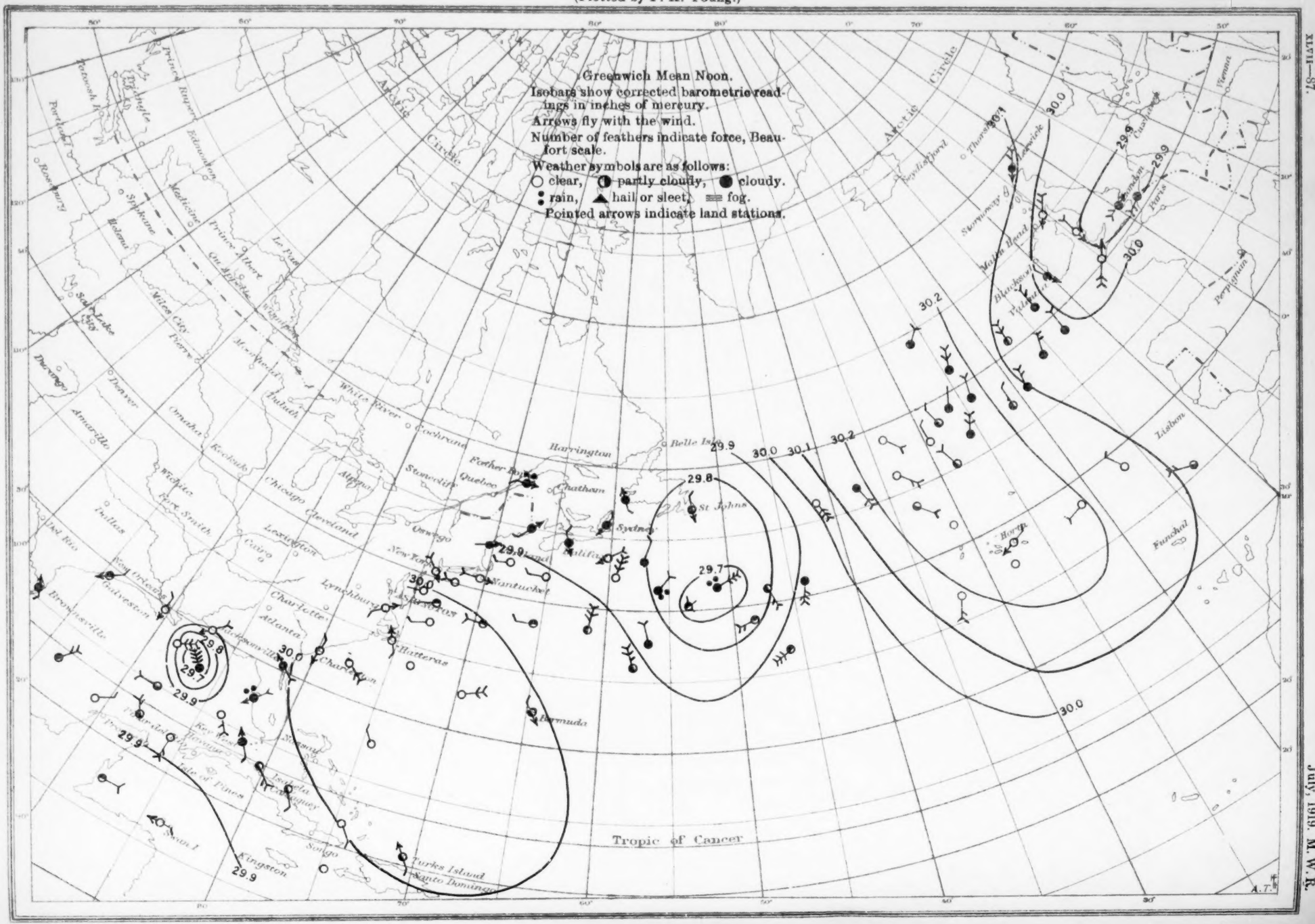

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy.
rain, hail or sleet, fog.
Pointed arrows indicate land stations.
Tropic of Cancer
Arctic Circle
Bermuda
Turks Island
Santo Domingo
Kingston
Havana
Key West
Galveston
Charleston
Hatteras
Nantucket
Halifax
St. John's
Sydney
Belle Isle
Harrington
Quebec
Father Point
Chatham
Cochrane
White River
Duluth
Chicago
Cleveland
Oswego
Atlanta
Charlotte
Lexington
Cairo
Amarillo
Denver
Pierre
Medicine Hat
Edmonton
Prince Rupert
Portland
Roseburg
Seattle
Spokane
Boise
Salt Lake City
Winnipeg
Fort William
Parry Sound
Toronto
Kingston
Ottawa
Montreal
Quebec
Father Point
Sydney
Halifax
St. John's
Belle Isle
Harrington
Chatham
Nantucket
Bermuda
Turks Island
Santo Domingo
Kingston
Havana
Key West
Galveston
Charleston
Hatteras
Atlanta
Charlotte
Lexington
Cairo
Chicago
Cleveland
Oswego
Duluth
White River
Cochrane
Amarillo
Denver
Pierre
Medicine Hat
Edmonton
Prince Rupert
Portland
Roseburg
Seattle
Spokane
Boise
Salt Lake City
Winnipeg
Fort William
Parry Sound
Toronto

Chart XI. Weather Map of North Atlantic Ocean, July 4, 1919.
(Plotted by F. A. Young.)

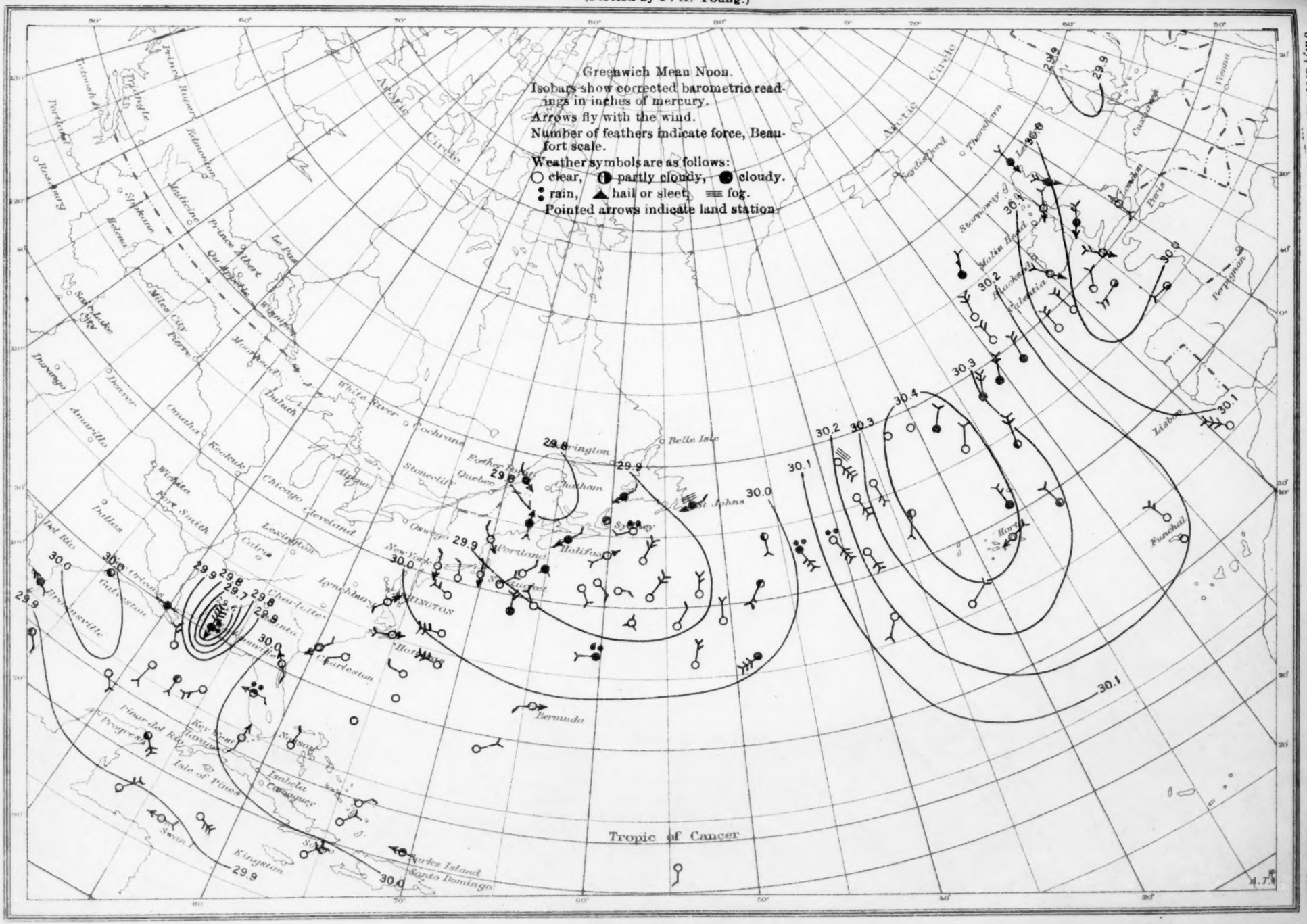


Chart XII. Weather Map of North Atlantic Ocean, July 5, 1919.

(Plotted by F. A. Young.)

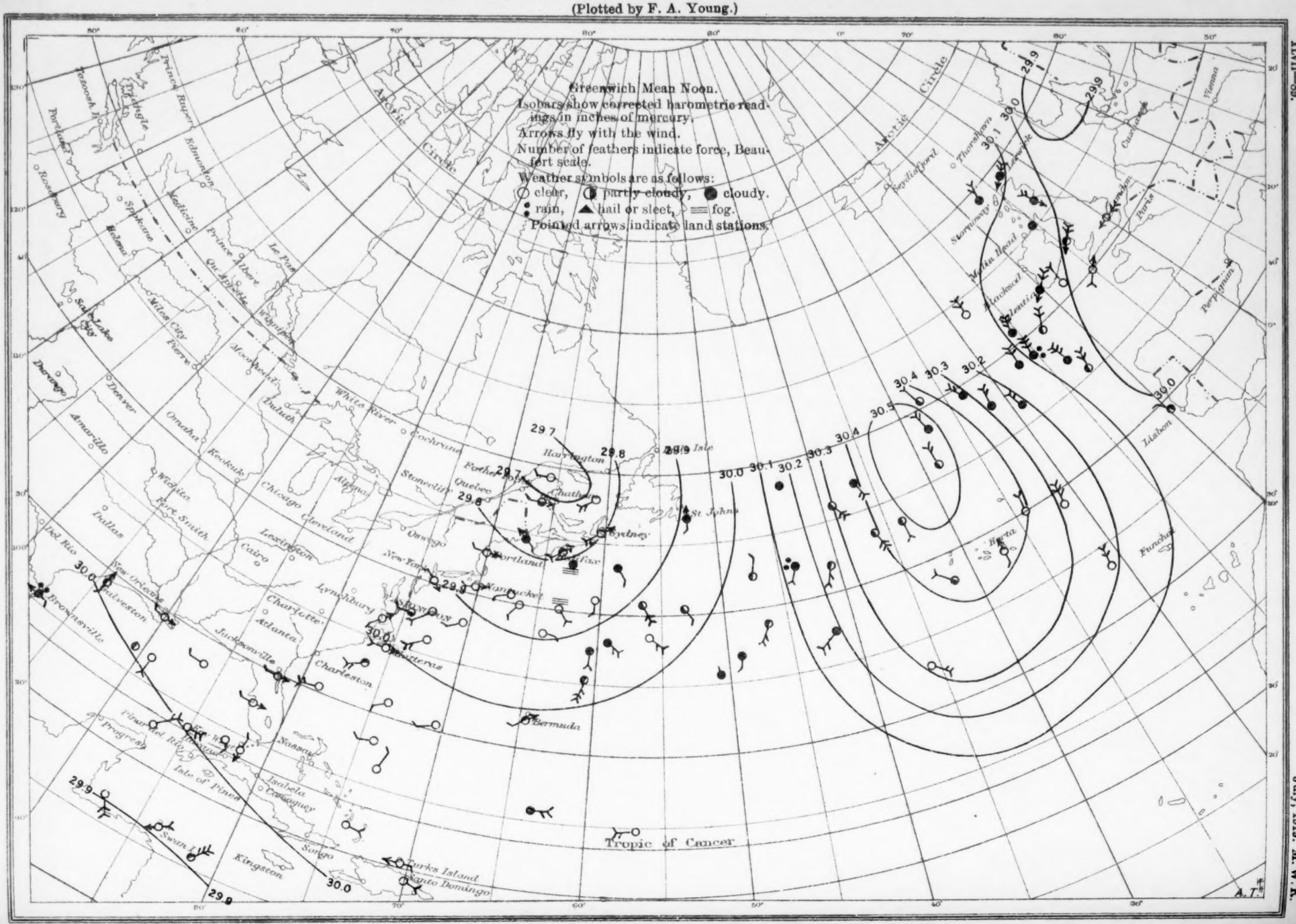


Chart XIII. Weather Map of North Atlantic Ocean, July 6, 1919.

(Plotted by F. A. Young.)

Chart XIII. Weather Map of North Atlantic Ocean, July 6, 1919.

(Plotted by F. A. Young.)

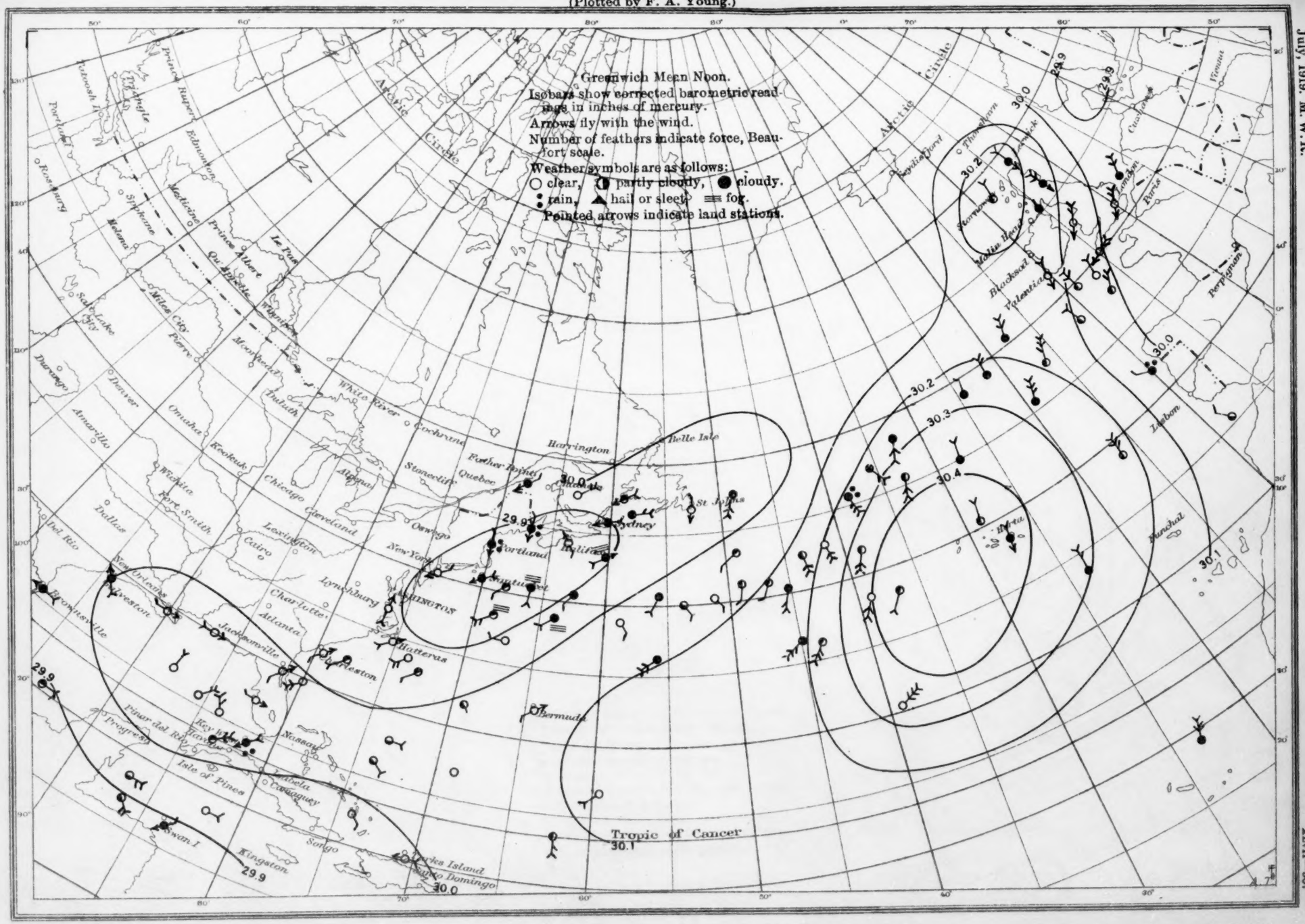


Chart XIV. Weather Map of North Atlantic Ocean, July 10, 1919.

(Plotted by F. A. Young.)

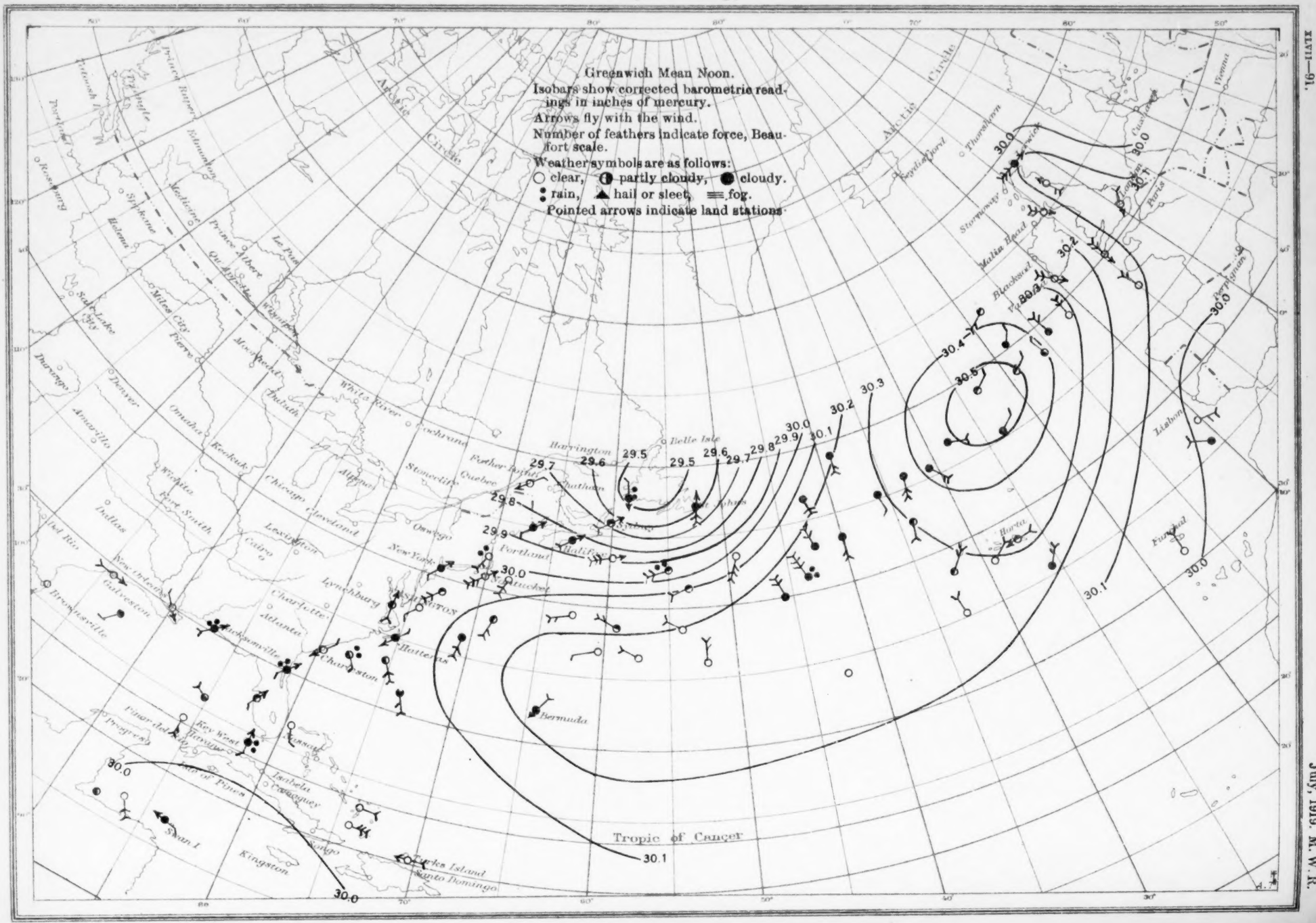


Chart XV. Weather Map of North Atlantic Ocean, July 11, 1919.

(Plotted by F. A. Young.)

Chart XV. Weather Map of North Atlantic Ocean, July 11, 1919.

(Plotted by F. A. Young.)

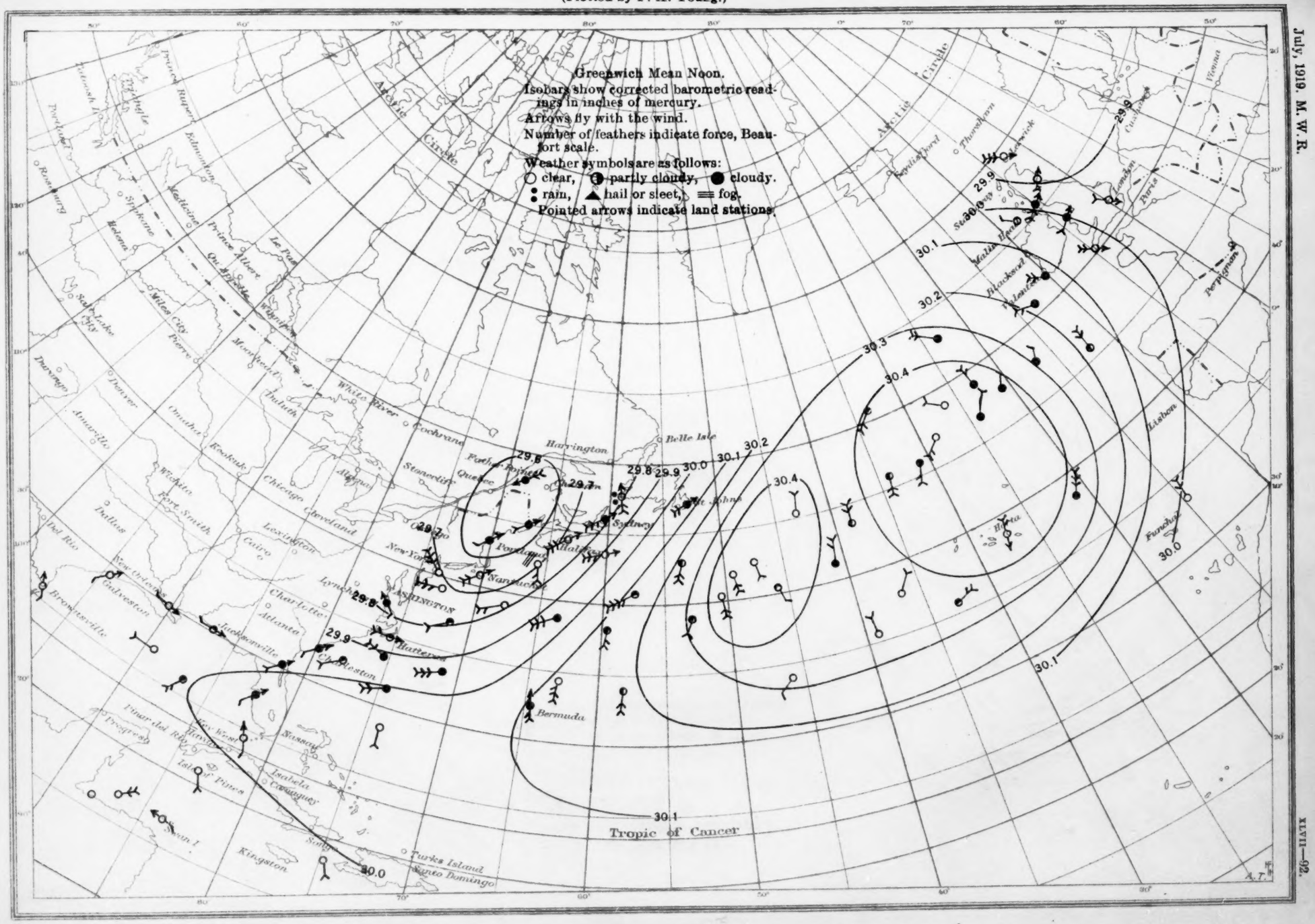


Chart XVI. Weather Map of North Atlantic Ocean, July 12, 1919.

(Plotted by F. A. Young.)

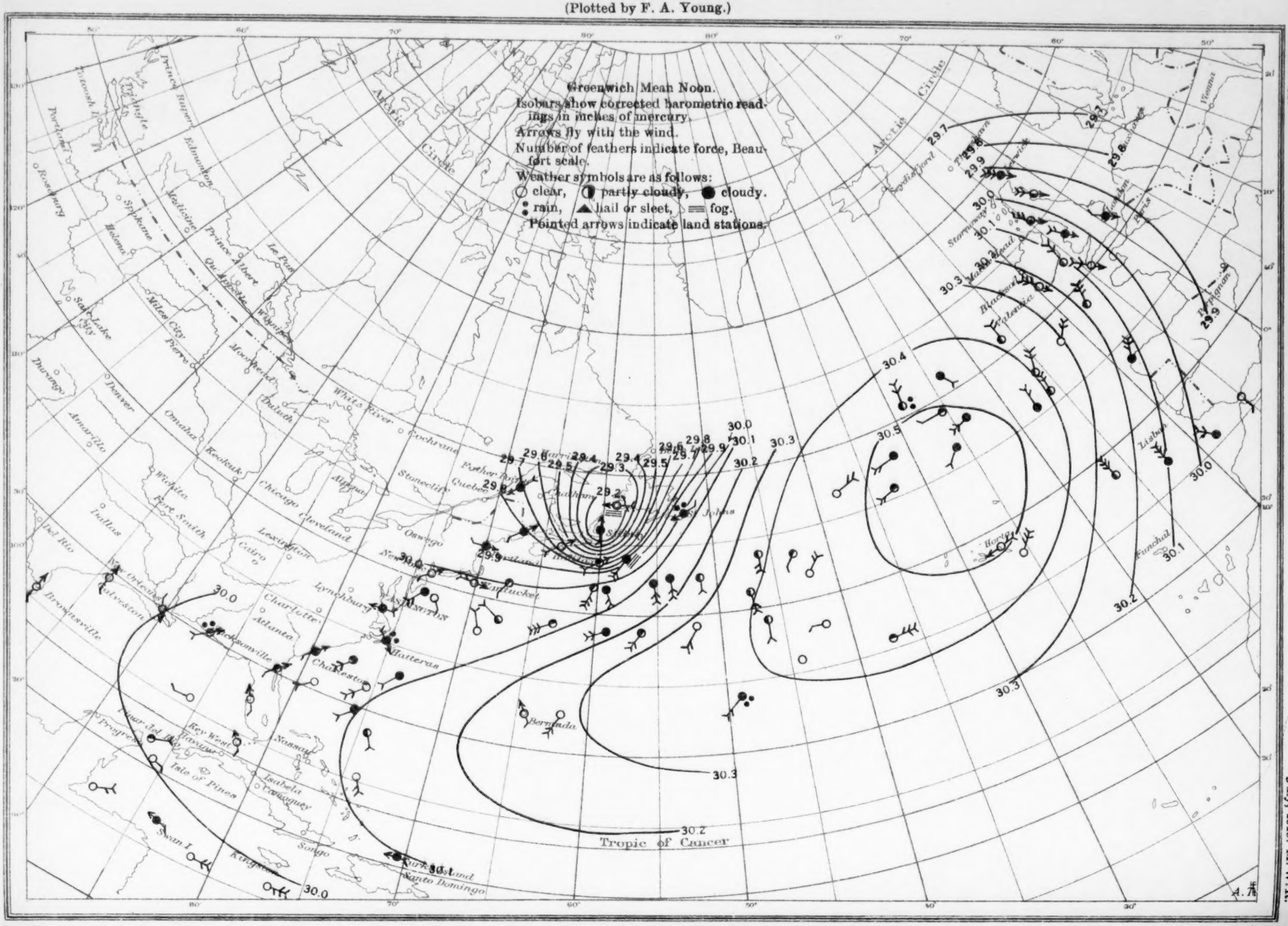


Chart XVII. Weather Map of North Atlantic Ocean, July 13, 1919.

(Plotted by F. A. Young.)

Chart XVII. Weather Map of North Atlantic Ocean, July 13, 1919.

(Plotted by F. A. Young.)

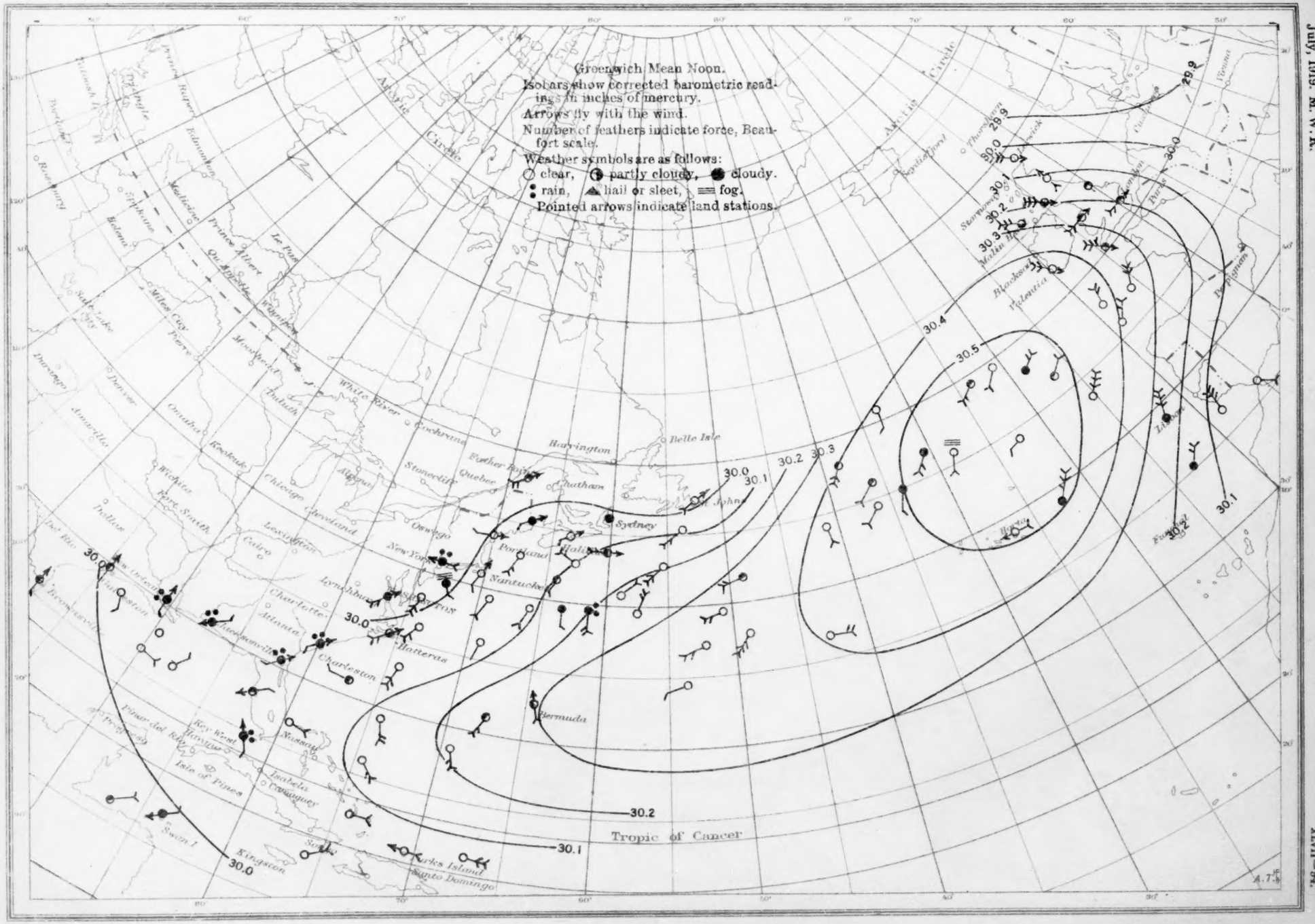
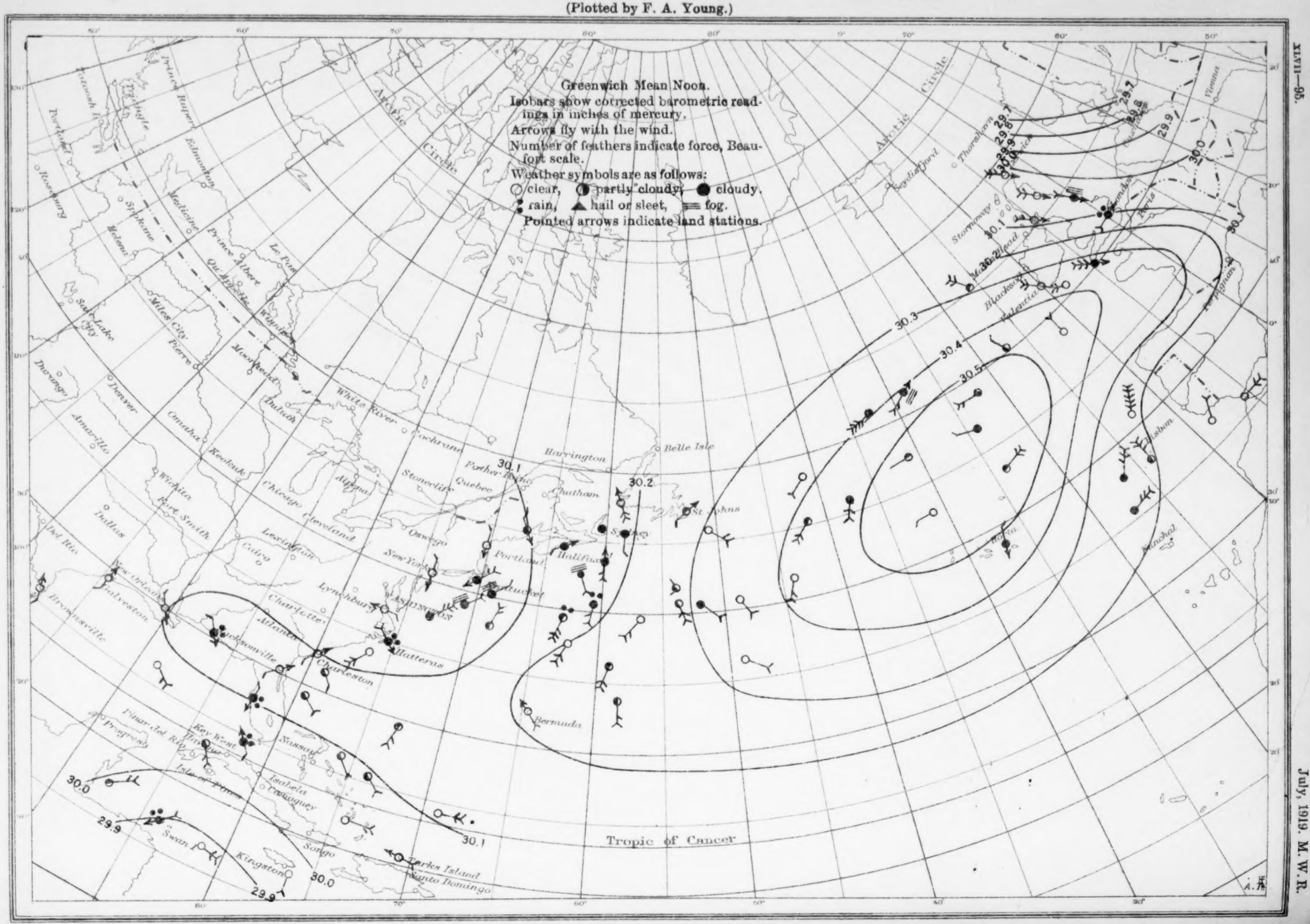

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy.
rain, hail or sleet, fog.
Pointed arrows indicate land stations.
Tropic of Cancer
Arctic Circle
Bermuda
Halifax
Sydney
Belle Isle
Harrington
Father Point
Quebec
St. Johns
Portland
Nantucket
Hatteras
Charleston
Key West
Havana
Isle of Pines
Kingston
Santo Domingo
Turks Island
Swan I.
Atlanta
Charlotte
Chicago
Cleveland
Oswego
New York
Denver
Omaha
Dallas
Duluth
Cochrane
Stonecliffe
Parry Sound
Edmonton
Prince Albert
Qu'Appelle
Winnipeg
Moosejaw
Medicine Hat
Calgary
Banff
Victoria
Seattle
Portland
Spokane
Salt Lake City
Miles City
Pierre
White River
Huron
Omaha
Kansas City
Wichita
Fort Smith
Memphis
Vicksburg
Shreveport
Galveston
Corpus Christi
Brownsville
Laredo
Eagle Pass
El Paso
Amarillo
Abilene
Fort Worth
Waco
Austin
Houston
Port Arthur
Beaumont
Lake Charles
New Orleans
Mobile
Montgomery
Macon
Augusta
Columbia
Wilmington
Norfolk
Cape Henry
Lynchburg
Roanoke
Knoxville
Chattanooga
Nashville
Louisville
Indianapolis
Cincinnati
Columbus
Toledo
Detroit
Grand Rapids
Milwaukee
Green Bay
Duluth
Minneapolis
St. Paul
Des Moines
Davenport
Rock Island
Peoria
Springfield
St. Louis
Cairo
Evansville
Terre Haute
Fort Wayne
Chicago
Grand Haven
Escanaba
Marquette
Port Arthur
Winnipeg
Prince Albert
Battleford
Medicine Hat
Calgary
Banff
Kamloops
Victoria
Seattle
Portland
Spokane
Boise
Salt Lake City
Grand Junction
Pueblo
Denver
Cheyenne
North Platte
Omaha
Sioux City
Huron
Pierre
Bismarck
Minot
Williston
Swift Current
Moosejaw
Qu'Appelle
Prince Albert
Edmonton
Battleford
Calgary
Medicine Hat

Chart XVIII. Weather Map of North Atlantic Ocean, July 14, 1919.

(Plotted by F. A. Young.)